
Metal Progress
DAVID 19
AFTON 59
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AM

Metal Progress

March 1960 . . . Volume 77, No. 3

This month's cover is a reproduction of a painting showing Project Mercury capsule in orbit over Cuba. The artist is David A. Willment, head, technical illustrating section, Langley Research Center, National Aeronautics and Space Administration.

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**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

How grid tray life was increased from 4 to 72 months

Electro-Alloys' knowledge of thermal fatigue extends service life 1700%

Figure 1 shows a grid tray used to move a solid cube of steel through a heat-treat furnace where side burners directed flame over the top of the tray, Figure 2. After 3-5 months' service, this tray would distort and fail, Figure 3. A photographic close-up of the failure is shown in Figure 4.

The user assumed the failure was due to inadequate pushing strength. With strengthened pushing ribs, the redesigned tray lasted only 2-3 months, half as long as the original design.

In view of this behavior, the user requested an Electro-Alloys design evaluation. The results are shown in Figure 5. *This new tray has a service life of 5-7 years!*

Pinpointing cause of thermal-fatigue failure

Electro-Alloys found that the *original tray* had been *overdesigned*. Extensive knowledge of the subtleties of thermal fatigue led to this conclusion.

Study of the furnace operation showed that the zones of heating and a heavy cooling concentration were the real causes of tray failure. They acted in this way:

On entry into the furnace, outside members of the tray heated more rapidly than inside members. As a result, expansion of these outside members was restricted by the cooler inside members. This set the stage for compression failure of outside members.

Farther in the furnace, inside members came up to temperature. But outside members had already forged in and were undersized. Now, expanding inside members subjected outside members to tensile stresses. This double reversal of stresses, compression then tension, during every cycle soon produced failure.

Any attempt to strengthen these outside members results in earlier failure because the increased mass leads to the metal fighting itself even more.

New design solves problem

The new design, Figure 5, called for raising the transverse ribs. This allowed the heated air to pass under the heavy die block. Through this simple change, it was possible to bring the die block to temperature more quickly and to eliminate the high temperature differential between outside and inside members of the tray.

The result is a 1700% increase in service from each tray.

Avoiding expensive thermal-fatigue pitfalls

Users and designers of heat-resistant castings are vulnerable, generally, to two pitfalls that lead to losses in service life and operating economy:

a. Assuming that an alloy operating well at 2000°F. will work just as well in a different application whose maximum temperature is only 1700°F.

b. Too much faith in the calculation of applied stresses as the measure of the casting's ability to withstand service conditions. This is reflected by increasing the size or number of restricting members . . . braces, gussets and tie rods.

These pitfalls are a natural outgrowth of the lack of information on thermal fatigue . . . the cause of 90% of all failures of heat-resistant castings.

Electro-Alloys is recognized as the leading authority on thermal fatigue and high-alloy casting design. Hundreds of case histories — such as the one reported here — and the widely published test data emanating from the Research Laboratory at Mahwah, N. J., are evidence of this.

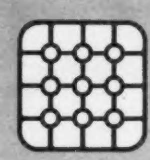

FIG. 1

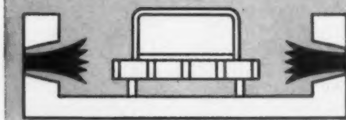

FIG. 2

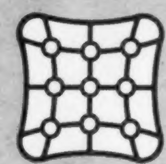

FIG. 3

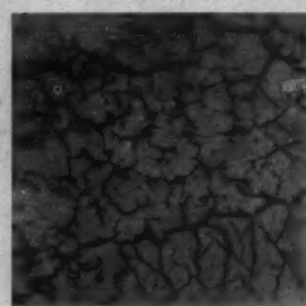

FIG. 4

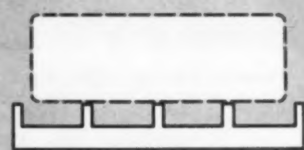

FIG. 5

● *Most recent of these reports is "The Mechanism of Thermal Fatigue," by H. S. Avery. Copies of this study are available on request. Simply write to Electro-Alloys Division, 2012 Taylor Rd., Elyria, Ohio.*

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

Circle 943 on Page 48-A

Metal Progress

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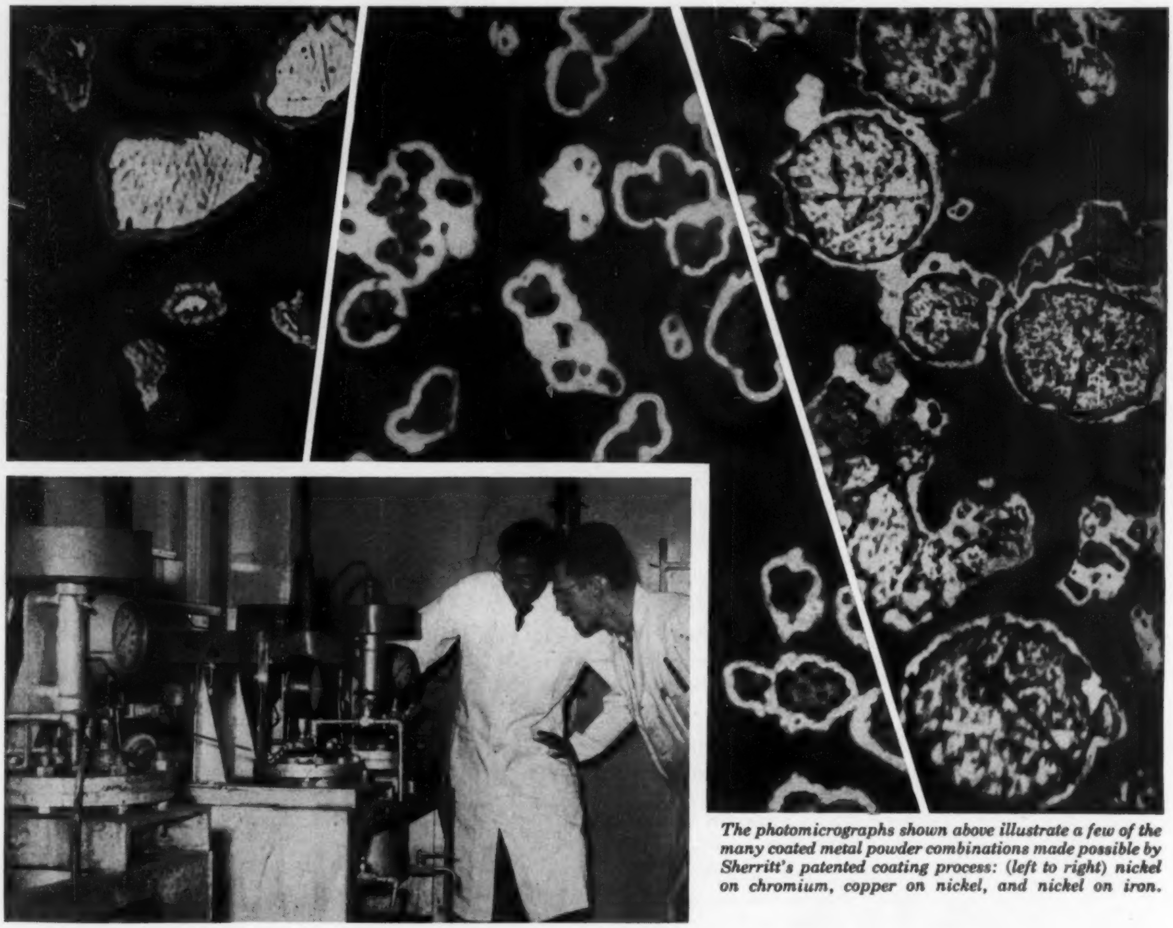

The photomicrographs shown above illustrate a few of the many coated metal powder combinations made possible by Sherritt's patented coating process: (left to right) nickel on chromium, copper on nickel, and nickel on iron.

new techniques for solid state nickel alloying

New metal coating techniques developed by the Sherritt Research Staff have greatly advanced the art of solid state alloying in powder metallurgy. These patented techniques permit controlled coating of minute metal or non-metal powders with pure nickel or cobalt.

By these new techniques metal powders sensitive to oxygen contamination while in process can now be protected by a continuous coating of nickel. The coating is intimately bonded over the entire particle surface so that compacts can be produced from a completely "nickel-plated" metal powder.

Perhaps the most significant contribution of the Sherritt developments to the art of powder metallurgy is the production of the metal/non-metal combination powders. With control of the coating completely in the hands of the metallurgist, the number of possible metal/non-metal combination powders suitable for compacting applications becomes almost unlimited.

SHERRITT

FOOTE MINERAL COMPANY is the exclusive sales agent for Sherritt nickel and cobalt in the United States and Canada. For product literature, prices, and delivery information, contact the Foote Mineral Company, 424S Eighteen West Chelten Building, Philadelphia 44, Pennsylvania.

SHERRITT GORDON MINES LIMITED

Circle 944 on Page 48-A

PRESS BREAKS

A. P. Ford ("Pete"), in charge of advertising for *Metal Progress* almost since the beginning, and his charming wife Jane sailed for Honolulu early in February. This is real news, for Pete has been so devoted to his work that his associates cannot remember the time when he really got away from the job for more than a day or two. "Press Breaks" will attempt an interview on his return, and present his views on the metallurgical situation at Waikiki Beach.

• • •

Robert H. Savage of H. G. Kroll Products, Inc., writes that he is sorry there is no available correlation of specifications. For example, what does C-1010 steel correspond to in the German DIN specification? It is of importance to his firm, for his engineering drawings may be used in Brazil, Australia, Japan or wherever . . . There probably is no German or English shorthand that means exactly the same thing as C-1010. As a matter of fact, the Editor-in-Chief knows of no adequate American dictionary which defines American metallurgical terms with any degree of accuracy or can be called complete in any respect. The difficulty is compounded in translating English terminology to American terminology. The technical dictionaries in French and German – the only ones he is acquainted with – appear to have been made a generation or two ago by people who were lexicographers, rather than metallurgists, engineers, or technologists. Thus if a translation is made from German or French by anyone except a practicing metallurgist, it has to be practically rewritten after it reaches our office – in other words, retranslated into American metallurgical jargon. Maybe a polyglot dictionary would be a good post-retirement project for an A-1 metallurgical intellect.

Faster Mailing

Metal Progress has for years been mailed by our printer around the 10th of the month, but because of the deliberate movement of Uncle Sam's second-class mail, the magazine has been delivered to ASMembers anywhere from the 15th to the 25th. This is too late. So the decision was recently made to move the mailing date up to the 29th of the month preceding date line. This has caused a minor revolution among our friends, the advertisers, and it may be of general interest to say something about production schedules.

Assume you wrap and mail 36,000 copies of a magazine on the 29th. It takes an efficient department to do that in one day – also an almost completely automatic bindery to fold and bind the printed sheets in one day (the 28th). Actual printing (press work) takes 48 hr. to make ready and print – two days and nights, around the clock. Every issue of *Metal Progress* has on the average 12 two-color forms, and several black-and-white forms which run simultaneously. Kable Printing Co. has four two-color presses and this means that these four run six days and nights continually to print a single issue of *Metal Progress*. But, since Kable Printing Co. also has other good customers, it means that printing of *Metal Progress* must be spread out over two working weeks – that is, the first form must start rolling on the 10th of the month preceding date line.

Before a form consisting mostly or exclusively of advertising can

go to press, *all* the plates must be on hand or *all* the type must be set. Preliminaries include composition, proofs, page paste-ups, page proofs and revises. At the very fastest – considering time for mail or express deliveries between production offices in Cleveland and printer in Mt. Morris, Ill., 500 miles away – it means that a deadline on receipt of plates must be set on the 5th, or copy on the 1st. Practically a month for production!

So much for the advertising forms. *Metal Progress* has a solid 64-page editorial block in the center of the issue. This goes to press first. That means that editorial work – copy reading, retyping edited copy, laying out the pages, making drawings and ordering engravings, setting type, reading galley proof, pasting up the page dummies, assembling type and cuts, examining and revising page proofs, locking up a form ready for the presses, with several airmailings between Cleveland and Mt. Morris – starts a full two months ahead of date of issue, and must be entirely complete 30 days ahead of mailing date.

Thus it is that production schedules are quite different for a slick monthly magazine than for a weekly periodical and especially for a daily newspaper where everything is high-speed, rough-and-ready, under one roof. (Even the daily has a week-long schedule for the Sunday supplements!)

● ● ●

The Editor-in-Chief is one of the reviewers cooperating with the Department of Defense and the Space Agency in reviewing currently published Russian documents in books. He appraises digests (in English, he hastens to say) in his rather limited field of metallurgy, and recently looked at an outline of a 350-page book which could never have been written by an American. Its title is "Conservation of Ferrous Metals" and its purpose is stated to be "to inform planners, economists and party workers in production and consuming establishments". You get some idea of the *size* of this bureaucracy when you note that 10,000 copies of the book were printed by the Moscow equivalent of the Government Printing office in Washington. You get some idea of what these planners are trying to do from the table of contents which includes such items as designing to avoid useless weight, selection of proper alloy for the duty, undue rejects in sheet metal works, reducing the circulating load of in-plant scrap – all matters normally taken care of by an intelligent staff of any firm in a capitalistic economy which intends to survive.

The final chapter heading, however is puzzling. It is "Socialistic Competition". I thought competition was a capitalistic virus.

● ● ●

Novelty – Maybe some Metal Progress readers have, like the Editor-in-Chief, wondered at its rather unconventional post office address – Metals Park, Novelty, Ohio. He passes, on one of the 20-mile routes between home and office, a little country store nearby Metals Park, and the sign says "Novelty Store". He speculates whether it is a store where novelties may be bought, or whether it is a general store located in Novelty, Ohio, or whether Novelty, Ohio, adopted its name because there was a novelty store near the township's center.

But wonderment does not cease there: As this is written (Feb. 2) the Editor-in-Chief looks out over the mineral garden and sees a ground hog shading his eyes from the sun and looking with appreciation on a bed of Christmas roses* in full bloom. Novel enough?

**Helleborus niger*, a confusing botanical name at that, for *niger* is Latin for black although the flowers are generous ivory cups like tulips.

Metal Progress

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RODNEY W. CRAMER, *District Manager*
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GEORGE H. LOUGHNER, *Production Manager*
METALS PARK, NOVELTY, OHIO, JORDAN 4-2271

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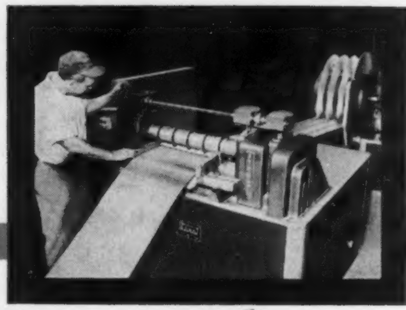
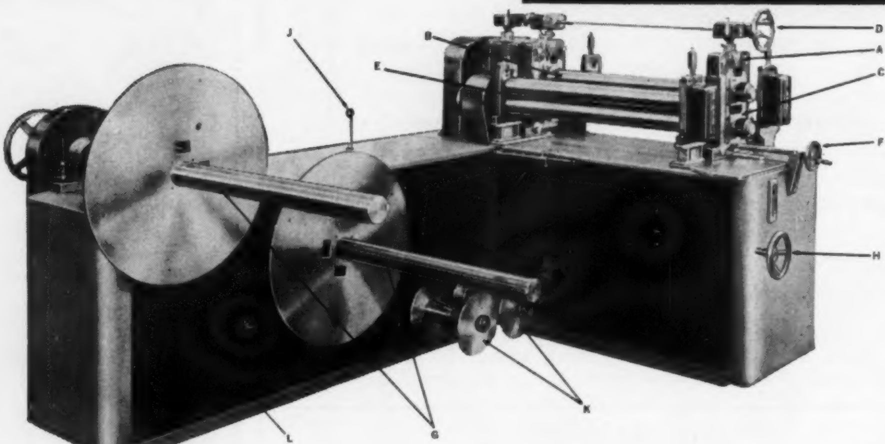
How STANAT SLITTERS *Offer* NEW ECONOMY





A. **HOUSINGS:** High tensile semi-steel castings, amply proportioned to minimize deflection.

B. **CUTTER ARBORS:** Heat treated alloy steel, precision ground and keyed full length for driving cutters.

C. **ROLLER BEARINGS:** Proportioned to take loads in excess of normal requirements. Rugged three (3) bearing design increases rigidity and minimizes arbor droop when outboard housing is swung aside. This construction aids in the production of clean, burr-free stock and prolongs cutter life.

D. **WORM GEAR SCREWDOWN:** Offers an effective means for providing simultaneous adjustment of both arbor ends. Arbor parallelism is not disturbed when vertical settings are changed nor when the outboard housing is removed for setup purposes.
A single micrometer dial facilitates precise positioning of the arbor and provides accurate control of cutter overlap, assuring increased cutter life.

E. **POWER DRIVEN ENTRY AND EXIT ROLLS:** (Available as original equipment or may be added at a later date). Entry rolls are driven through an over-running clutch which disengages automatically as stock enters bite. Exit rolls are driven through an adjustable friction clutch. Upper and lower rolls are gear driven and adjustably spring loaded against each other. Idler exit rolls are also available.

F. **CRANK-OFF MECHANISM:** Provides a convenient means for removing the outboard housing to gain access to the cutter arbors.

G. **DUAL RECOILER:** Permits alternate winding of slit strands and completely eliminates fan out, thus preventing cambering of stock. Recoiler Shafts accommodate all types of coiling devices including the exclusive Stanat core plate arrangement shown below.

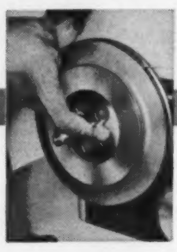
H. **STOCK TENSION CONTROL:** Adjustable from the operator's position while machine is running, offers a simple and convenient method of obtaining tightly wound, uniform coils.

J. **RECOILER SPEED SELECTOR:** Permits choice of recoiler shaft speed to insure proper tension over wide range of coil inside diameters. Ideal for custom slitting operations with core plate recoiling.

K. **DUAL SCRAP WINDERS:** One for each trim cut—with individual friction clutches, wind the scrap into two tight easily disposable bundles.

L. **WELDED STEEL BASE:** Heavy plate construction fully encloses the drive.

ACCESSORY EQUIPMENT: A full line of accessories is available as optional equipment to suit your particular application.



CORE PLATE RECOILER—provides easy removal of tightly wound slit coils without telescoping or unwinding; frequently permits one man operation of entire line.
CORE PLATE Being Removed With Finished Coil

A full line of Stanat Slitters is available ranging from light duty to heavy duty pull through types.
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Write for Bulletin #569.

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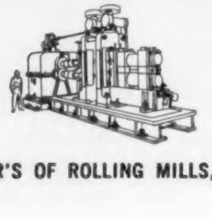

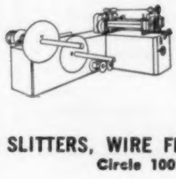

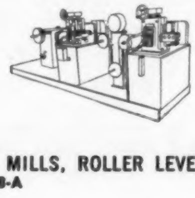

MFR'S OF ROLLING MILLS, GANG SLITTERS, WIRE FLATTENING MILLS, ROLLER LEVELERS AND BULL BLOCKS

Circle 1005 on Page 48-A

■ The direct-reading spectrometers at Bridgeport Brass Company plants are used for fast, accurate alloy composition analyses. These units, integrated with pneumatic sample tube systems, make possible complete quality-control analyses in a matter of minutes from the time the samples are taken until the reports are telautographed back to the melt floor.

Results—obtained quickly and economically by direct reading spectroscopy — permit Bridgeport Brass Company plants to maintain elements within alloy composition limits.

"NATIONAL" GRAPHITE helps speed alloy composition analyses

"National" graphite rod grades AGKS and SPK are being used for the analysis of 95 to 100% on all castings from furnaces at the Bridgeport Brass Company's copper base alloy and aluminum plants. Grade SPK, a newly introduced product, is providing excellent reproducibility and has cut running time approximately five hours/week on troublesome jobs. It is preferred on samples containing over 90% copper to provide hotter discharges which rapidly vaporize the metal, providing faster analyses. In addition, the improved texture and density offer better machinability and more "shots" per rod.

Whether you use rods, pre-forms or powders, specify "National" for your spectroscopic work.

UNION CARBIDE

"National" and "Union Carbide" are registered trade-marks for products of

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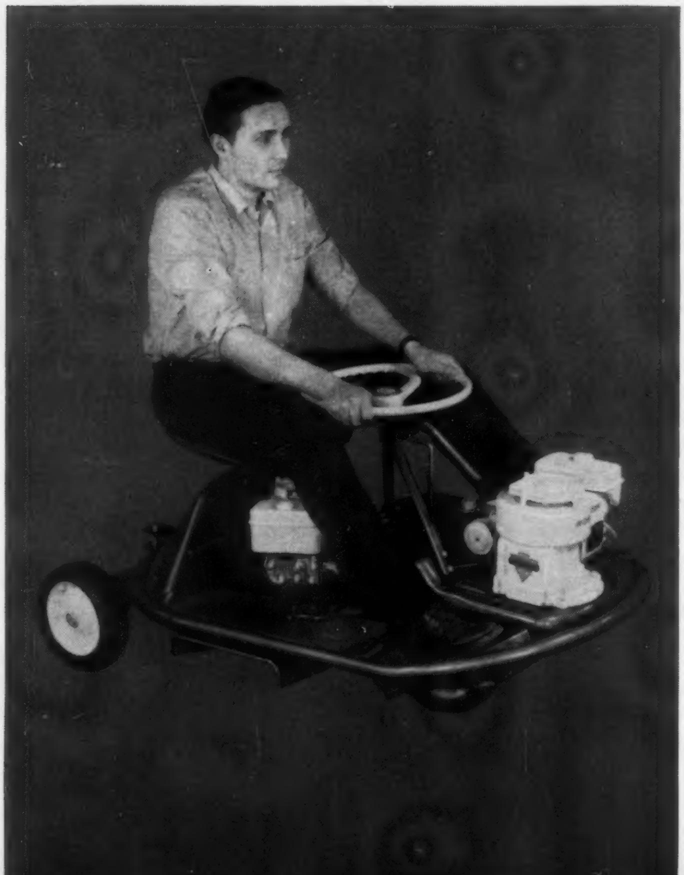
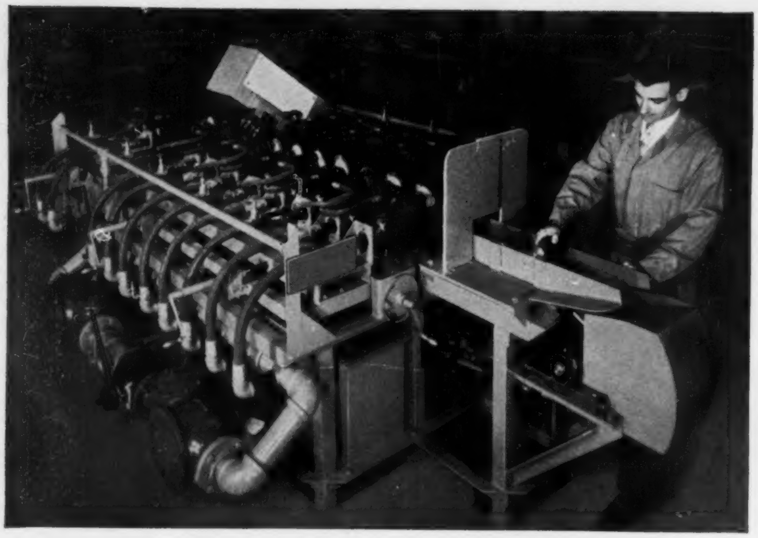
PERFORMANCE UP...

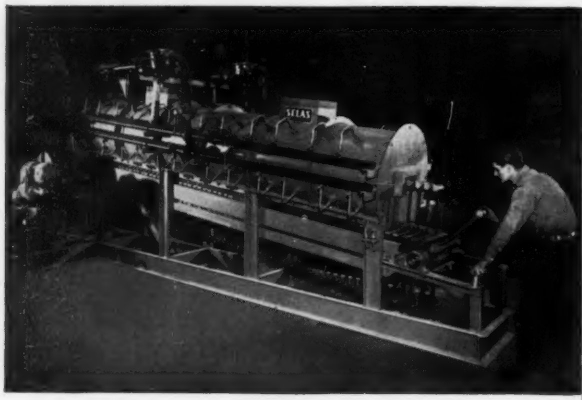


ROBERTON MANUFACTURING COMPANY, Chicago, Illinois, uses 44 Republic NYLOK® Self-Locking Fasteners to hold power units firmly in place in their Roberton Twin Power Riding Mowers. NYLOK'S special nylon inserts assure positive locking in any position. Displacement of the insert produces strong lateral pressure, preventing any play despite extreme vibration.

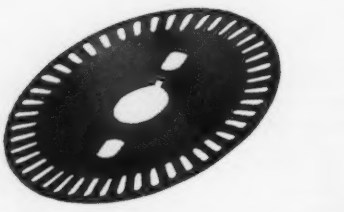


SELECTIVE HARDENING: Both faces of sledge-hammer-heads are selectively hardened and tempered in a continuous operation. Tempering, previously requiring hours, now performed in minutes. Machine handles wide variety of sizes, shapes and widths of heads. Integration with preceding grinding step enables operation of machine with no additional labor.

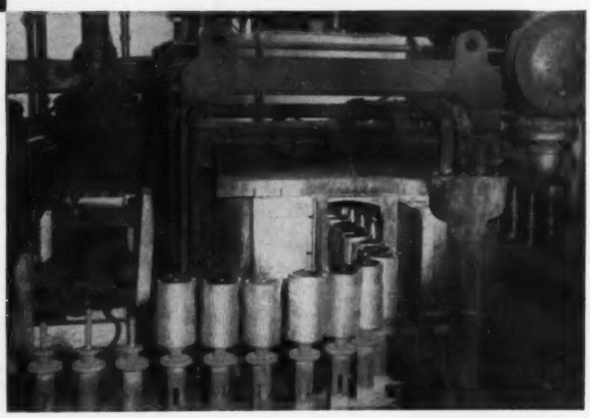
Here's How Industry Cuts Costs



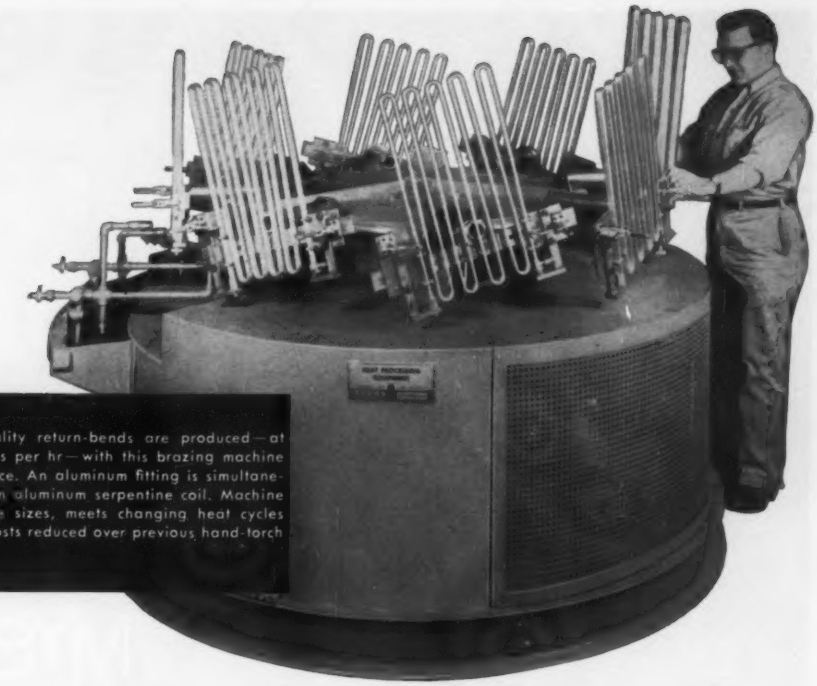
HEATING FOR FORGING: Brass slugs—⅞ to 2" diam., 2½ to 8" long—are heated to 1390°F in this automatic machine at high production rates. Selas fast, uniform heating produces fine grain size, improved physical properties.



ANNEALING: Electric motor stator and rotor laminations are annealed to develop required electrical characteristics. Laminations, 2½" to 10" O.D., stacked 6" high on spindle fixtures, are heated uniformly and quickly, then control-cooled, in continuous operation. Complete cycle takes only 35 min, increases production rates substantially over conventional methods.



is your reward



BRAZING: Consistently high quality return-bends are produced—at production rate of 130 assemblies per hr—with this brazing machine which occupies a 6 x 6' floor space. An aluminum fitting is simultaneously brazed onto each end of an aluminum serpentine coil. Machine accommodates varying work-piece sizes, meets changing heat cycles and production demands. Labor costs reduced over previous hand-torch brazing method.

Improves Product Quality

with SELAS heat processing equipment

The installations on these pages demonstrate how Selas automatic heat processing equipment

- cuts operating costs
- increases production rates
- minimizes in-process inventory
- reduces labor requirements
- saves valuable floor space
- improves product quality

Specifically designed and custom-built to meet your individual production requirements and job specifications, Selas heat processing equipment employs time-proven standardized engineering features for longtime operating dependability and minimum initial investment. Problems usually associated with divided responsibility are avoided since Selas starts-up and services every machine it designs and builds.

Selas automatic or semi-automatic heat processing equipment can help you produce better products at lower costs. At your convenience—without obligation to you—a Selas field engineer would welcome the opportunity to survey your requirements.

For this free, personal service, or for literature on any of the heating operations shown here, write Mr. W. B. Troupe, General Industry Div., Selas Corporation of America, 33 Dreshertown Road, Dresher, Pa.

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SELAS CORPORATION OF AMERICA
DRESHER, PENNSYLVANIA

HEAT AND FLUID PROCESSING ENGINEERS · development · design · construction

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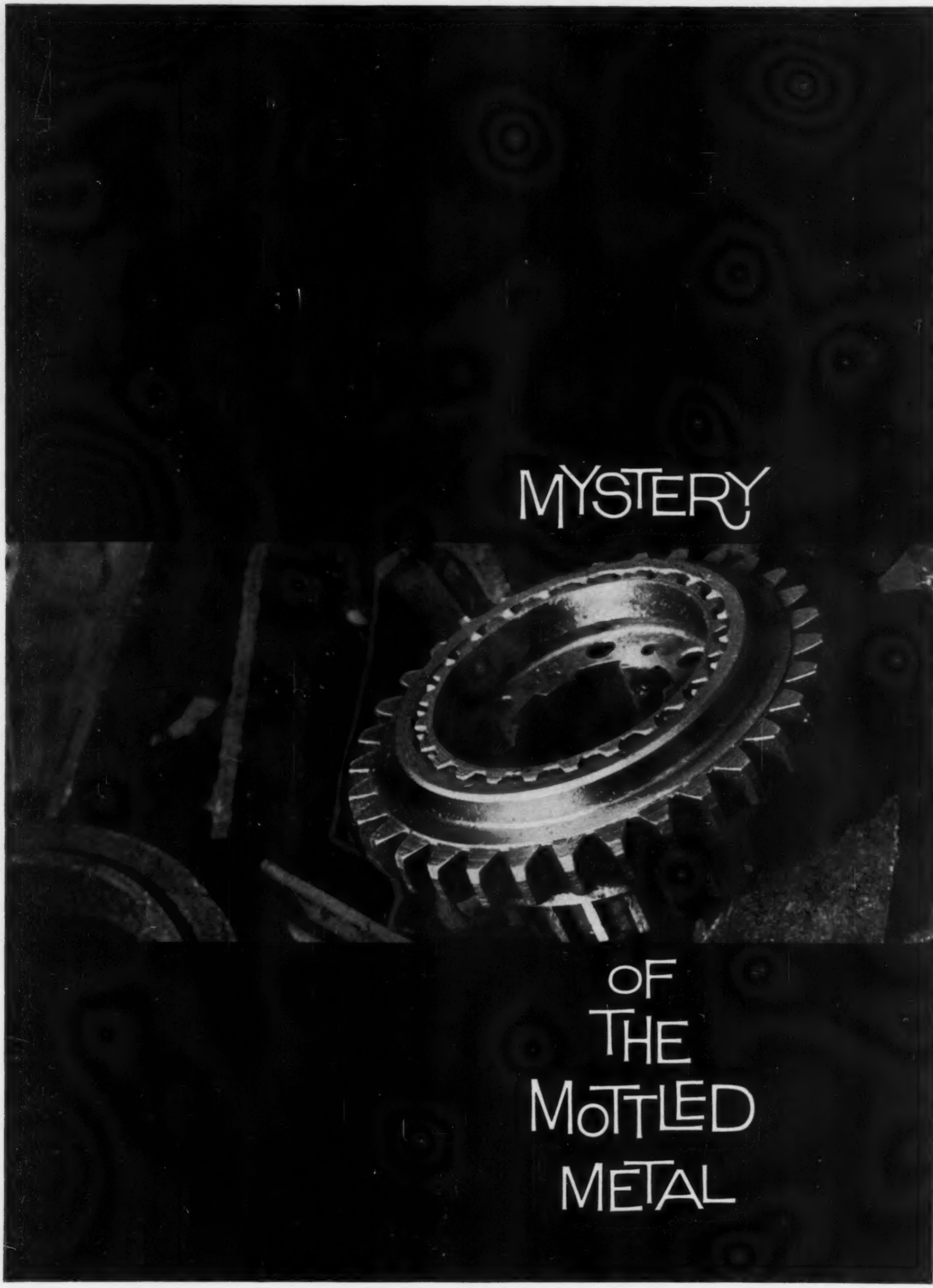
MYSTERY
OF
THE
MOTTLED
METAL

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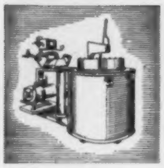


Once upon a time we just built Heat Treating Furnaces. Continuing experience in this fundamental application of heat to industry led naturally to our development of other types of industrial heating equipment—Melting Furnaces, Ceramic Kilns, High Frequency Units, Atmosphere Generators, Pilot Plant and Laboratory Equipment. Today it is pretty well known that, however a product needs heat, there is Lindberg equipment to best apply it. This broad background privileges us to offer industry—

A PLUS DIMENSION in LINDBERG SERVICE

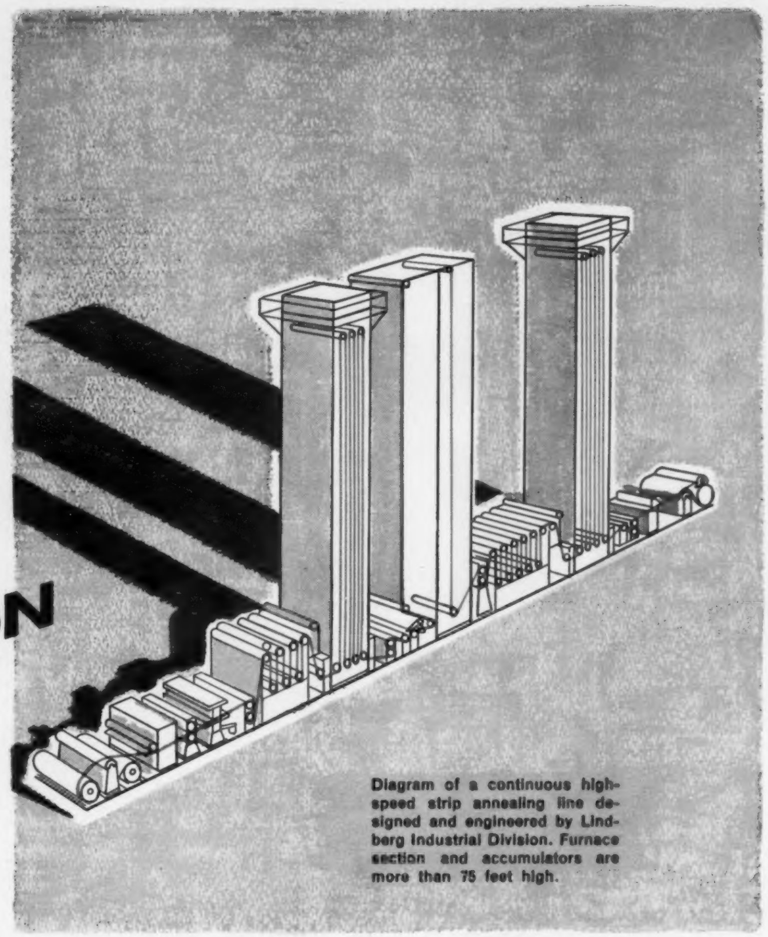


Diagram of a continuous high-speed strip annealing line designed and engineered by Lindberg Industrial Division. Furnace section and accumulators are more than 75 feet high.

We are more than the mere builders of equipment. Lindberg offers today a complete answer to any problem requiring the application of heat to industry. If you will give us your specific requirements for a part or a product, we will develop the right processes, design, engineer and install the equipment and facilities to fulfill satisfactorily your quality and product standards.

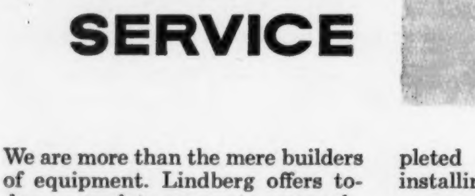
This service covers broad requirements—from plant layout and construction to automated production lines or just specially engineered industrial heating equipment efficiently integrated into your production processes.

For example, Lindberg Industrial Division has recently completed or is in the process of installing such varied projects as:

- Complete plant layout and equipment for brazing honeycomb
- Foundations, roof, lighting, furnace installations for heat treating raw aluminum products
- A fully automated production line for heat treating plow shares
- Installation of two large ceramic kilns embodying a new concept of making high-refractory bricks
- Complete plant and automated production line for preparing, enameling and drying household ranges.

When you offer your industrial heating problems to Lindberg you get the combined skills of what we believe to be the country's finest group of engineers and technicians in the field, with many years experience in the solution of all types of "heat for industry" problems. Above all, since Lindberg provides a complete service, design, fabrication, installation, you depend on just one reliable source with the full responsibility for the satisfactory performance of your installation. So give your industrial heating problems to Lindberg. You'll be happy with the result.

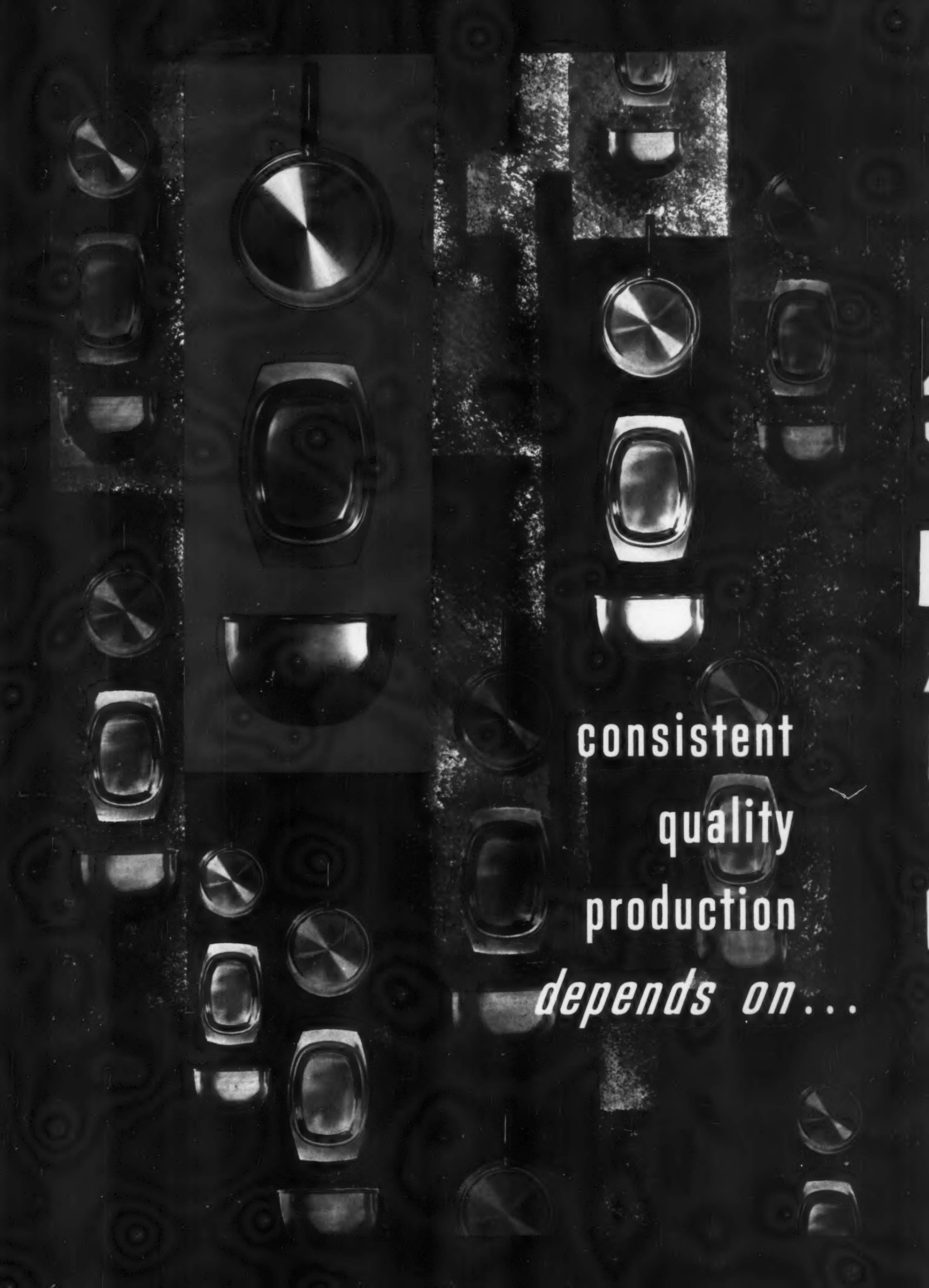
Lindberg Field Engineers are available in 23 major industrial centers in the United States and Canada (see classified telephone directory) or write direct to:



Lindberg Industrial Division
LINDBERG ENGINEERING COMPANY
2321 West Hubbard Street, Chicago 12, Illinois
Los Angeles Plant: 11937 South Regentview Avenue, Downey, California
In Canada: Birlefco-Lindberg, Ltd., Toronto

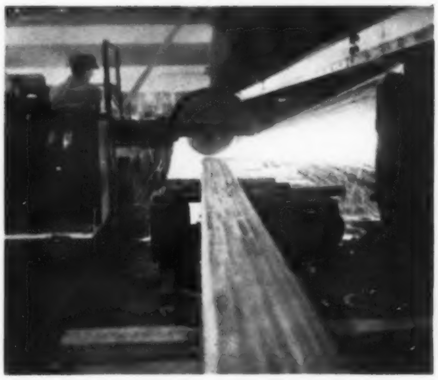
LINDBERG **heat for industry**

Circle 952 on Page 48-A


consistent
quality
production
depends on...

Every phase of melting from the selection of scrap to the pouring of ingots is carefully controlled with laboratory precision by constant testing.

The quality of billets and slabs governs the quality of finished products.



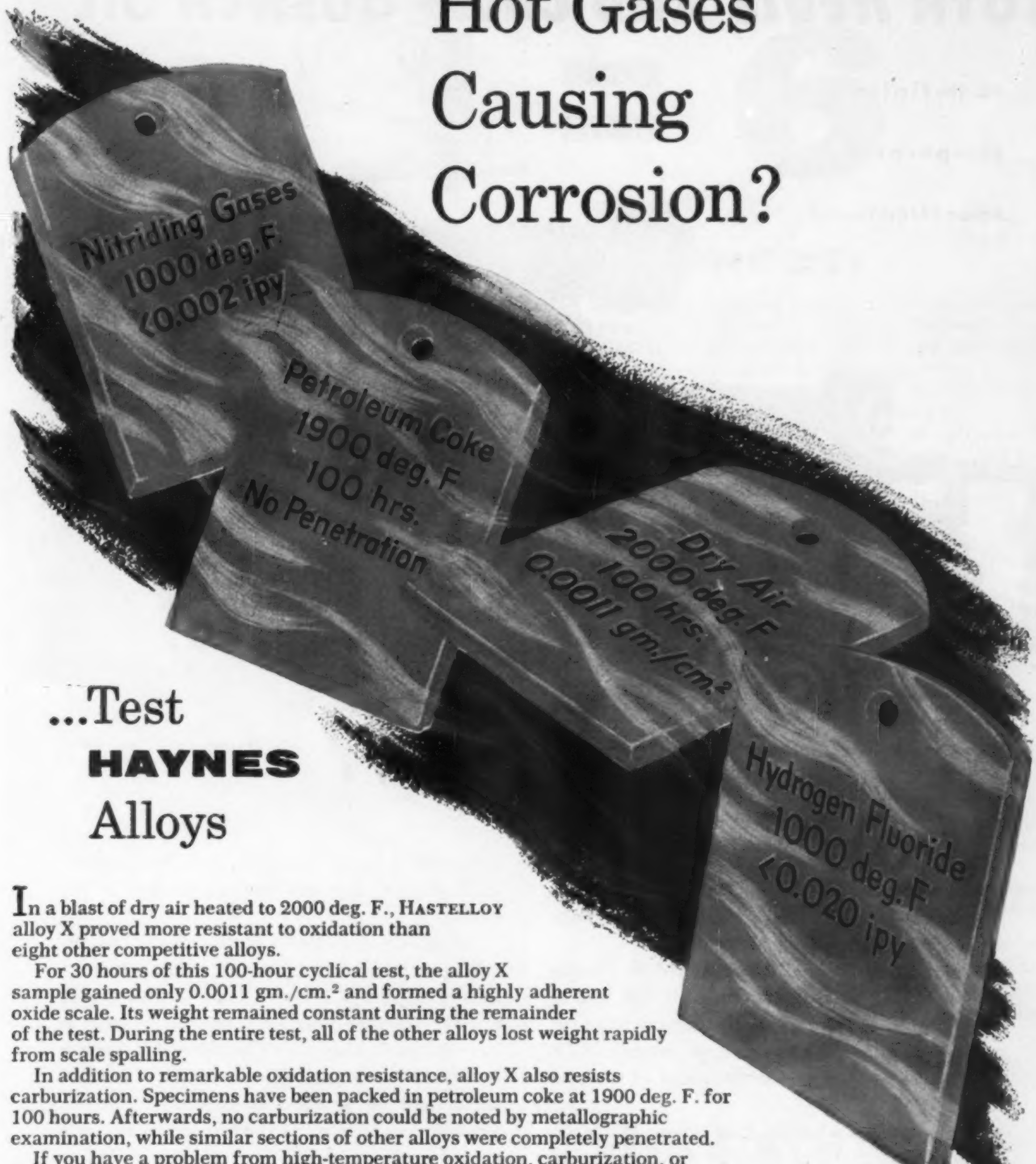
Conditioning of slabs and billets to exacting standards assures flawless surface finishes.

stainless steel

Typical of all J&L equipment is the industry's most modern 4-block wire drawing unit.

The industry's largest bar inventories guarantee fast service. Comparable inventories of sheet and strip will assure speedy service for flat rolled products.

Hot Gases Causing Corrosion?



...Test **HAYNES** Alloys

In a blast of dry air heated to 2000 deg. F., HASTELLOY alloy X proved more resistant to oxidation than eight other competitive alloys.

For 30 hours of this 100-hour cyclical test, the alloy X sample gained only 0.0011 gm./cm.^{2} and formed a highly adherent oxide scale. Its weight remained constant during the remainder of the test. During the entire test, all of the other alloys lost weight rapidly from scale spalling.

In addition to remarkable oxidation resistance, alloy X also resists carburization. Specimens have been packed in petroleum coke at 1900 deg. F. for 100 hours. Afterwards, no carburization could be noted by metallographic examination, while similar sections of other alloys were completely penetrated.

If you have a problem from high-temperature oxidation, carburization, or from corrosion due to nitriding gases or chemicals in flue gases, there is a HAYNES alloy to help you reduce maintenance. Find out for yourself by testing them.

We'll gladly send you samples. But to make sure we send you the alloy or alloys most nearly suited to your need, we ask that you send a letter outlining your own particular conditions. If you would like to learn more about alloy X, ask for a copy of the booklet, "HASTELLOY Alloy X."

HAYNES
ALLOYS
HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

The terms "Haynes," "Hastelloy," and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

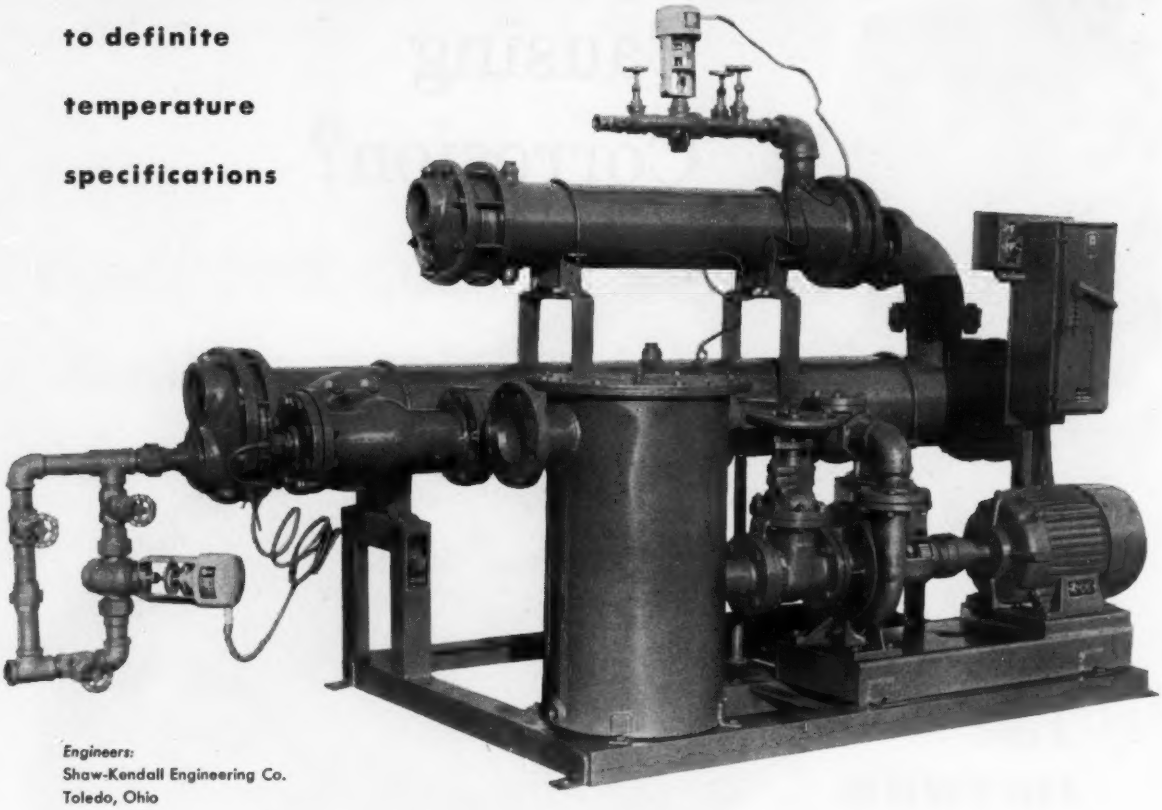
Circle 840 on Page 48-A

BOTH *Heats* AND *Cools* QUENCH OIL

to definite

temperature

specifications



Engineers:
Shaw-Kendall Engineering Co.
Toledo, Ohio

At the Chevrolet Motor Division of General Motors Corporation, Toledo, Ohio, this B&G Self-contained Quench Oil unit performs a double duty in controlling quench oil temperatures.

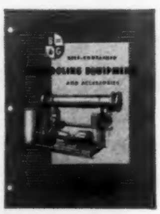
On the cooling side, it is required to remove 368,000 BTU/hr. from the oil. At a flow rate of 250 GPM, the oil enters the cooling unit at 140°F and leaves at 120°F. Cooling water enters at 85°F and leaves at 95°F and is circulated at the rate of 74 GPM.

When used as a heater, 1500 gallons of quench oil flowing at 250 GPM is heated within two hours from 60°F to 110°F. The heating medium is steam at 10 psig and is passed through the shell of the heater.

Controlled quenching temperatures is the certain way to maintain uniform quality in heat-treated metals and to avoid excessive sub-standard rejects. Whether your heat treating volume is large or small, B&G Self-Contained Oil Coolers can be engineered to your requirements...or, components can be furnished for assembly on the job. The services of the B&G engineering staff are always available.

B&G Quench Tanks
Properly designed to induce maximum turbulence in the quench oil, B&G Quench Tanks are available in standard models or can be built to meet any specific quenching requirement.

Send for this combined Catalog and Simplified Selection Manual for B&G Self-Contained Quench Oil Coolers.



B & G

Hydro-Flo*

OIL QUENCHING SYSTEMS

BELL & GOSSETT COMPANY

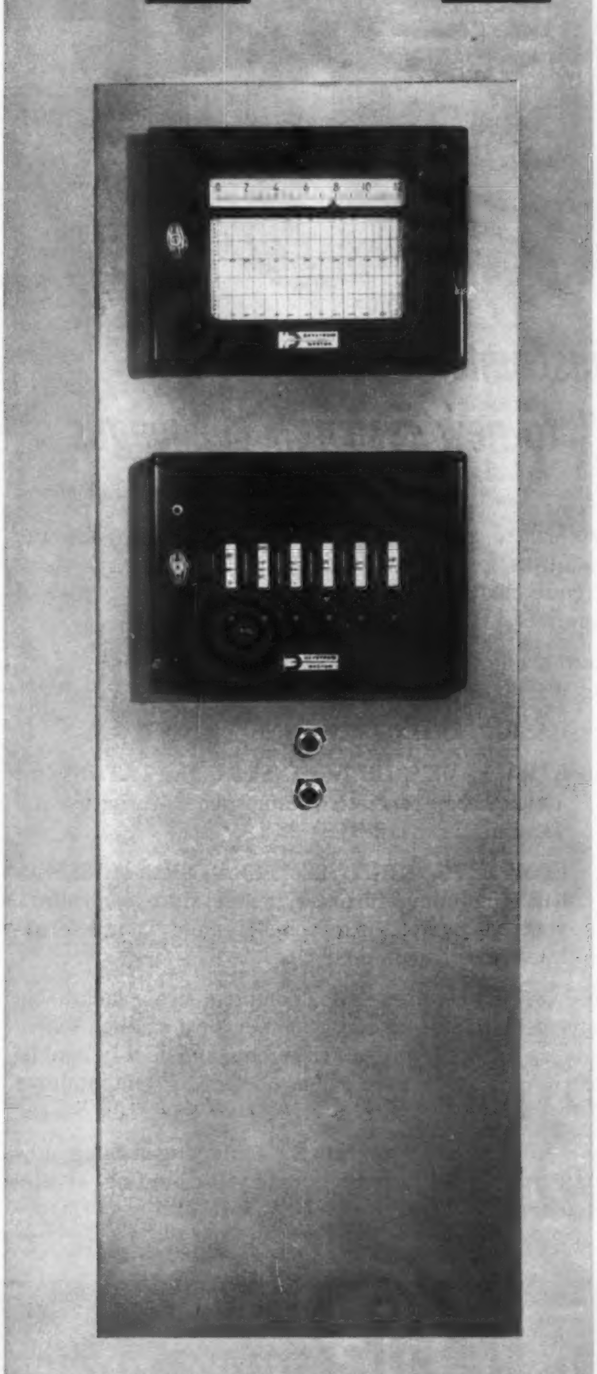
Dept. GC-16, Morton Grove, Illinois

*Reg. U.S. Pat. Off.

Canadian Licensee: S. A. Armstrong Ltd., 1400 O'Connor Drive, Toronto 16

Circle 841 on Page 48-A

1+1=6



CORRECT!

Maybe not in second grade, but correct with this new Daystrom-Weston economy "package": the Model 6134 Multi-Point Controller and Model 6702 Multi-Point Recorder combination.

Up to six individual recording controllers can now be replaced by this two-unit set-up.

Up to 50% in cost reductions can be realized over individual units when 6 points are specified for each instrument. As many as 18 additional points can be added to the recording unit if desired.

Savings are not limited to initial cost alone. Compactness, flexibility and accurate, reliable operation free from maintenance worries all contribute to substantial long-range savings as well.

Both independent units employ the exclusive D-PAK® Constant Current Source, eliminating many conventional components such as batteries . . . standard cells . . . standardizing mechanisms. Their unitized design makes for easy accessibility of interior parts . . . provides precise 2- or 3-position electric contact control.

Two distinctly separate circuits afford dual protection against overtemperature. Alarm circuits set for individual points in the Recorder provide high or low temperature cut-off as desired. Two separate or one common thermocouple can be used for each point – as the installation demands.

Control packages, including panels and accessories, can be suited to your own specific application.

For further information, contact your local Weston representative . . . or write to Daystrom-Weston Sales Division, Newark 12, N. J. In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.

DAYSTROM WESTON

World leader in measurement and control

DAYSTROM-WESTON INDUSTRIAL INSTRUMENTS include a full line of recording and controlling potentiometers with strip and circular charts; mechanical recorders and indicators for pressure, temperature and flow; and non-indicating controllers, both electric and pneumatic.

Circle 842 on Page 48-A

NEW PRODUCTS

Nonferrous Metals

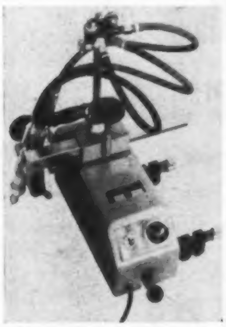
Tungsten Ingots

Ingots weighing 500 lb. of 85-15 W-Mo alloy are now regularly made by *Oregon Metallurgical Corp.*, and plans are under way for commercial production of 1000-lb. ingots. Made by the double-melt vacuum arc process, the metal in the 10-in. diameter and 14-in. long ingots is sufficiently uniform so it can be machined directly into such parts as rocket nozzle inserts for solid-fuel ballistic missiles. Carbide tools are necessary.

For further information circle No. 615 on literature request card, p. 48A and B.

Tool Materials

Flame Cutting Machine



The illustration shows a simple, light (35 lb.) straight-line cutting machine. Cuts may be bevelled at any angle in plate up to 4 in. thick. The device is merely placed on the plate to be cut. Its speed may be varied from 24 to 120 ft. per hr. both forward and backward. Fuel gas and oxygen hoses enter the torch head and they are mixed immediately before combustion. While acetylene is the recommended fuel, hydrogen, propane or natural gas can be utilized. The motor can accept either a.-c. or d.-c. current at 110 or 220 volts. *Milo Mfg. Co.*

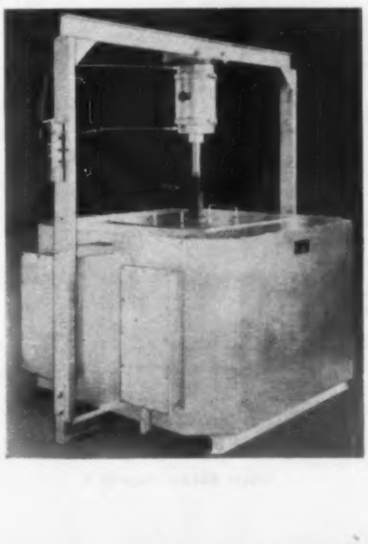
For further information circle No. 616 on literature request card, p. 48A and B.

Industrial Heating

Sintering Furnace

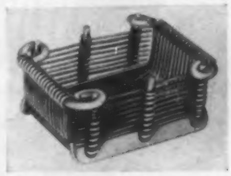
A new electric, hot load testing furnace, capable of pressure sintering at temperatures to 2750° F. at pressures to 200 psi., has been announced by the *Pereny Equipment Co.* Infinite control of the pressure exerted on the heated load is provided by a manual control lever operating a hydraulic cylinder and ram mounted on the pressure frame. Power and temperature controls are mounted on a separate panel. Chamber size is 15 by 15 by 18 in. deep.

For further information circle No. 617 on literature request card, p. 48A and B.



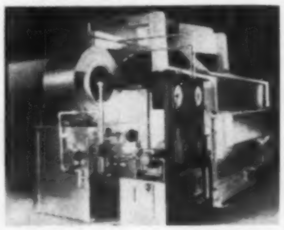
Molybdenum Trays

Baskets and trays made of the refractory metal molybdenum are fabricated of bars and rods without welds by looping the rods around stanchions as shown in the photograph. Since 50% of the sides and bottom are open, a minimum of interference is offered to circulation of heating medium, whether molten bath or atmosphere. They can operate in nonoxidizing environments to 3000° F. and a little higher. *Bix Co.*



For further information circle No. 618 on literature request card, p. 48A and B.

Flattening Furnace



Die quenching is not a new operation but the use of dies to keep a sheet flat while tempering, aging at elevated temperature, or precipitation hardening is not so common. *Waltz Furnace Co.* offers such a furnace capable of, for example, flattening wing sections, for aircraft in sizes up to 6 by 8 ft. It has front and rear doors; the hearth contains a stationary flat block of cast iron; the steel superstructure supports a hydraulic unit with ram going through the roof to a movable upper die. A variety of controls hold the temperature at any point between 250 and 1100° F.

For further information circle No. 619 on literature request card, p. 48A and B.

Cleaning and Finishing

Salt Cleaner

"No Bleed" is a new liquid which removes traces of entrapped salts from freshly electroplated parts (especially powder metal compacts) remaining after normal hot water rinsing. The solution operates for 2 to 5 min. at 250° F., or until visible gassing ceases, after which the cooled parts are put through a degreaser. *Heatbath Corp.*

For further information circle No. 620 on literature request card, p. 48A and B.

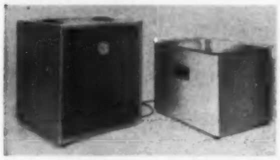
Cleaning Gun

The "Vonarx Air Gun" vibrates a gang of hardened steel or beryllium copper needles against the surface to be cleaned and at the same time shoots a blast of compressed air to blow away the loosened fragments of rust. The needles are also reciprocated by the compressed air. Each needle operates independently so they reach

Circle 844 on Page 48-A

into pits or adjust to varying contours. The needles last 200 to 400 hr.; replacement costs are 7 to 10 cents per hr. The guns weigh from 6 to 13 lb. and are useful for cleaning weld seams, castings, rust, stripping paint and mildly roughing surfaces prior to metallizing. *Swissair Tool Corp.* **For further information circle No. 621 on literature request card, p. 48A and B.**

Ultrasonic Cleaner



Self-contained generator and associated 13-gal. tank is offered by *National Ultrasonic Corp.* The unit is especially adapted for work requiring average energy. The electrical unit plugs into a normal 110 to 115-volt alternating current outlet and delivers average power continuously at 500 watts. One-third of the tank bottom is covered with transducer crystals – the actual radiating surface is 96 sq.in. The stainless steel tank has rounded corners for easy cleaning.

For further information circle No. 622 on literature request card, p. 48A and B.

Spray Booth Stripper

Now available from *Frederick Gumm Chemical Co.* is a waterfall spray booth stripper which prevents excessive foaming and keeps steel booth walls from corroding. The compound "Clepo 57-T", is continuously recirculated. As the paint is washed down from the walls into the circulating tank, it separates from the top of the wash water, can be drawn off into a separate reclaiming tank, and sometimes reclaimed profitably.

For further information circle No. 623 on literature request card, p. 48A and B.

Cleaner and Phosphatizer

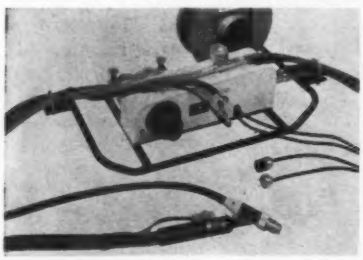
Heatbath Corp. has introduced a new product, "Morphos", for simultaneous cleaning and phosphating of iron and steel articles in spray washing machines. It produces a coating useful to prevent chipping and peeling of paint and to increase its adhesion, to localize corrosion (should painted parts become damaged), to increase over-all resistance to corrosion, and to produce a more attractive finish with less paint.

For further information circle No. 624 on literature request card, p. 48A and B.

Welding and Joining

Arc Welding Torch

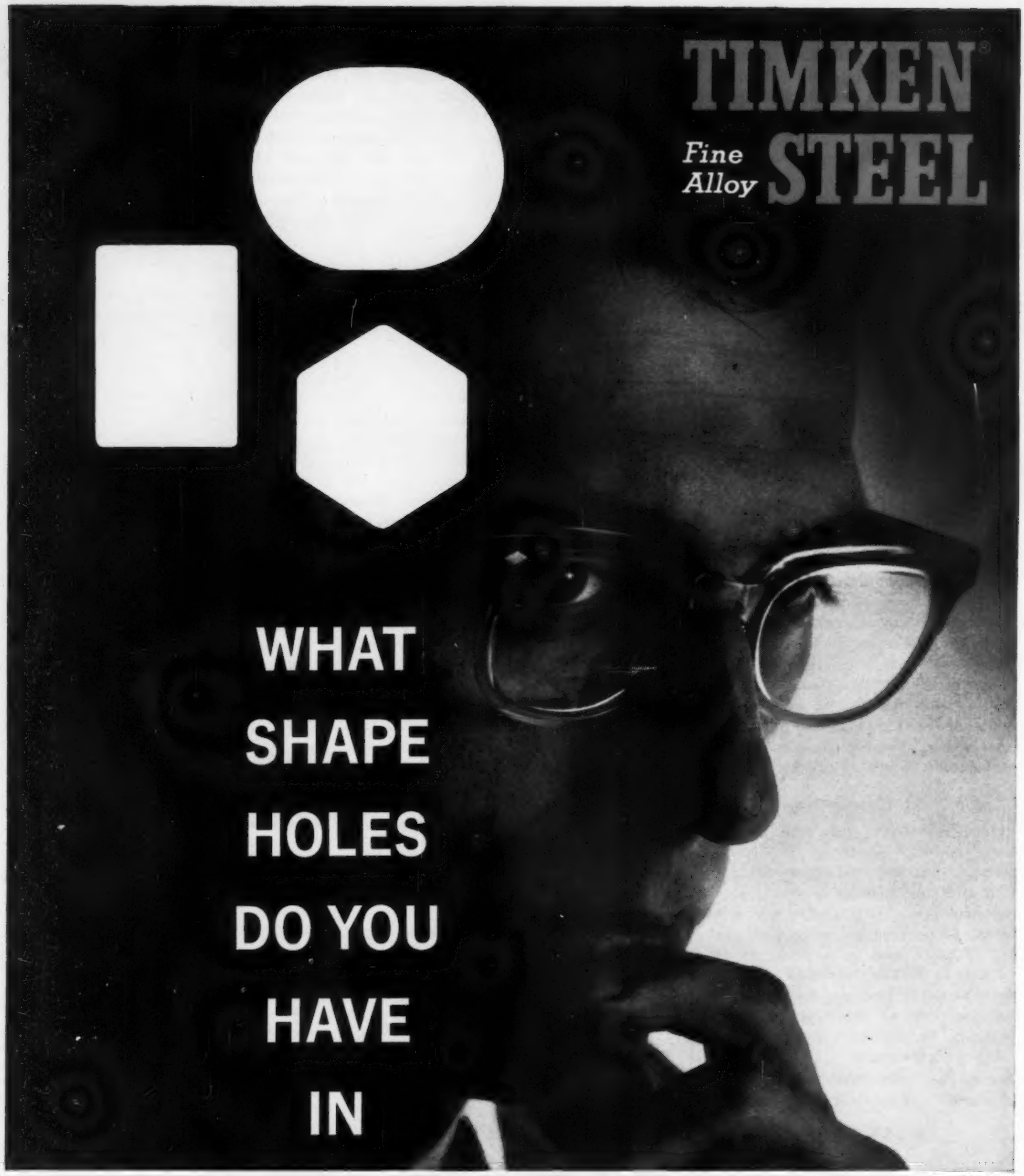
Skid-mounted WC-1 welding control and the AM-1 torch, both illustrated, are designed for d.-c. welding current and may be used in semi-automatic welding processes. The control can pass through an 18-in. manhole, weighs only 55 lb. and avoids intricate electronics. The wire is driven by a motor with governor, and can feed wire 3/64 to 3/32-in. diameter at any rate from 55 to 500 in. per min. The torch can also be used with other controls. It has a water cooled cup. *National Cylinder Gas. Div.*



For further information circle No. 625 on literature request card, p. 48A and B.

High-Production Welder

Resistance welders getting their current from the discharge of capacitors have two disadvantages – first, it may take as long as 2 sec. to recharge the capacitor, and second, their peak demand is for power as high as 200 kw. These are said to be eliminated by the "spike" welder, illustrated, wherein the capacitors are arranged so as to give 120 pulses a second, each of about 1 millisecond duration. The current drawn from the supply line is correspondingly low as is also the heat generated in the weld zone; the very short time does not permit much energy to escape by conduction. It results that – for example – a stud can be welded to vinyl or lacquer-coated steel

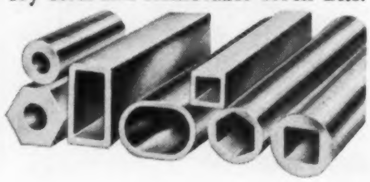


MIND?

No matter. Whether you need a round hole, a square hole or a hex hole for the hollow parts you manufacture, you can eliminate costly machining operations. Start with Timken® seamless steel mechanical tubing and your first step will be finish grinding.

With a special cold working operation, the Timken Company can supply you a variety of shapes and sizes of high quality alloy steel in all common analyses. You get extra strength from the forged quality and spiral grain flow of rotary pierced tubing. And because we target the process to *your* end use, you're assured superior quality and uniformity in your products.

For more information on how Timken seamless steel tubing can save you time and money in all your hollow parts, write: The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.



Circle 846 on Page 48-A

without discoloration; chromium and copper-plated metal can be joined. *Weldex Div., The Metal Craft Co.*

For further information circle No. 626 on literature request card, p. 48A and B.

Production Soldering

Much labor ordinarily required for applying flux and tin or silver solder to assemblies has been saved by use of a pasty mixture of the two which can be squeegeed to the required place either manually – or, better, automatically in repetitive mass production. The latter operation has now been speeded up to as much as two per second by controlling operations by an electric eye (bottom, left, of adjoining photo) which scans parts as they pass on ceramic fixtures held on a conveyor belt, and controls the operations of the applicator or gun shown at right center. *Fusion Engineering.*

For further information circle No. 627 on literature request card, p. 48A and B.

Self-Fluxing Brazing Alloys

The various "Nicrobraz" brazing alloys already available from *Wall Colmonoy Corp.* are now produced (without change in alloy composition) with the addition of a flux which evaporates during the joining operation. Difficult-to-braze alloys, such as many high-temperature alloys and alloys of titanium or aluminum, can thus be joined in hydrogen or argon atmosphere. The joint is wetted and cleaned a little further than the alloy spread. The vaporizing flux attacks no known base metal.

For further information circle No. 628 on literature request card, p. 48A and B.

CO_2 Welding Gun

Air Reduction Sales Co. is now marketing a new design of welding gun for mild steel using the "buried" metal-arc process shielded with carbon dioxide gas. It can use hard welding wires ranging from 0.035 to 0.093 in. in diameter. A goose-neck nozzle assembly adapts it for hard-to-reach locations, and the number of connections has been reduced by combining the power cable and the electrode casing.

For further information circle No. 629 on literature request card, p. 48A and B.

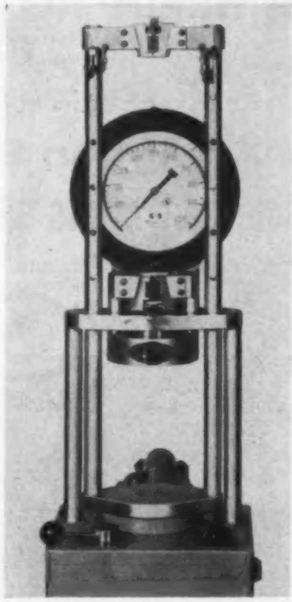
Arc Welding Machines

Designed to N.E.M.A. standards for heavy-duty industrial use, the new "M & T Murex A C" machines have capacities ranging from 200 to 500 amperes and provide optimum arc characteristics and stability for wide range of electrode sizes. Current control is continuously adjustable throughout the entire range. The whole unit and all controls are enclosed in a steel box with hoisting eyes and steel skids. *Metal & Thermit Corp.*

For further information circle No. 630 on literature request card, p. 48A and B.

Inspection and Control

Small Tensile and Compression Machine



A new "Model LPT" testing machine for small loads is being made by *Detroit Testing Machine Co.* It uses four interchangeable load cells of 100, 200, 600, and 1000 lb. capacity, each with its own gage and graduations to match. The equipment is operated hydraulically, the pump being driven by a small motor which can be plugged into an ordinary lighting circuit. The loading equipment is adjustable as to rate of load, and the machine can accommodate tensile specimens up to 12 in. long, compression up to 6 in. high.

For further information circle No. 631 on literature request card, p. 48A and B.

Precision Potentiometer

Minneapolis-Honeywell Regulator Co. now has a single six-dial model of potentiometer wherein vulnerable parts

of the circuitry are shielded against static electricity and temperature changes. It has a resolution of 0.01 microvolt and is suitable for precision calorimetry and various other work in standards or physical research laboratories. The instrument has three galvanometer keys for low, moderate and high sensitivity and also a thermo-free reversing key. A double model has duplicate sets of dials for two independent inputs.

For further information circle No. 632 on literature request card, p. 48A and B.

Portable X-Ray

Illustrated is a "Norelco PG 300", portable industrial X-ray unit, completely self-contained and weatherproof for outdoor operation if desired. It weighs 230 lb., and can inspect 3 in. of steel. Normally it is operated intermittently, but it can be run continuously when water cooling channels are

connected. Power requirement is 9-amp., 220-volt, 50 to 60-cycle current. The focal spot is 2.3 mm. diameter, the emergent beam angle 40°, giving excellent radiographic definition. *Philips Electronic Instruments.*

For further information circle No. 633 on literature request card, p. 48A and B.

Low-Range Pyrometer

Pyrometer – literally, "fire measurer"–ordinarily means just that, but many times such a piece of equipment would be much more convenient than a mercury thermometer for reading temperatures from −40 to +200° F. The electromotive force produced by a thermocouple junction at such low temperature differences from the "cold junction" is so small, however, that the utmost precision is required in the indicators, leads and in the thermocouple itself. This has now been achieved by *Illinois Testing Laboratories* in their "Alnor Type 2300 B" equipment. Several designs of thermocouples are available, with needle-like protection tubes, tubes with windows for fast response, and surface thermocouples of fine wire mounted in a swivelling nylon head for self-alignment on the surface to be investigated.

For further information circle No. 634 on literature request card, p. 48A and B.

heat treating SALTS

CYANAMID Eliminate scaling and decarburization in heat treating, without special atmospheres – through the use of salt baths. Use AEROHEAT® heat treating salts for uniform, economical results in electric, gas or oil fired furnaces. For further information about Cyanamid chemicals for the metal industry or technical assistance, mail coupon.

CYANAMID CHEMICALS FOR THE METAL INDUSTRY

HEAT TREATING SALTS: AEROHEAT 1700 1800°F to 2400°F; AEROHEAT 1400 1650°F to 2150°F; AEROHEAT 1000 1050°F to 1850°F; AEROHEAT 1200 1300°F to 1600°F; AEROHEAT 400 450°F to 1100°F; AEROHEAT 300 325°F to 1100°F; Nitriding Salt 900°F to 1150°F.

CARBURIZING AND CASE HARDENING COMPOUNDS: AEROCARB® E and W, A and B Case depths .005" to .045", S and R, D Case depths .005" to .150"; AEROCASE® 28 and 510 Case depths .005" to .050".

OTHER CYANAMID METAL CHEMICALS: AEROMET® metallurgical additives for nitrogen addition to and desulfurization of ferrous metals; AEROSOL® surface active agents; metallic stearates; acids and other heavy chemicals.

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Company____________________

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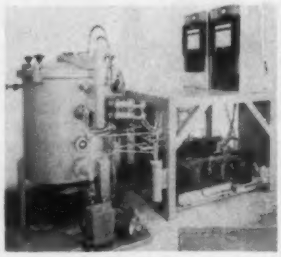
____

Position____________________

Circle 850 on Page 48-A

Production Equipment

4700° Furnace

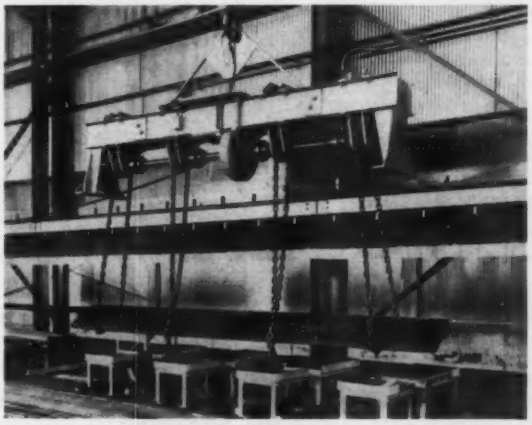


The furnace shown in the engraving has the necessary electrical equipment in a compact assemblage. Resistor is a split graphite tube; the hot zone in the size illustrated is 6 in. diameter by 15 in. high, although in companion designs it measures 30 in. diameter by 48 in. high. The furnace operates at partial vacuum or at positive pressure of nonoxidizing gases. Efficient insulation ("expanded" carbon or carbon dust) cuts radiation losses to a very small value. *Vacuum Specialties Co., Inc.*

For further information circle No. 635 on literature request card, p. 48A and B.

Slab Turnover Device

Heppenstall Co.'s material handling division have constructed a device for handling, transporting or rolling-over steel slabs up to 50 in. wide, 20 ft. long, and weighing up to 25,000 lb. As illustrated, it is turning over a large slab



of stainless steel so it can be surface ground on the other side prior to rolling into strip-sheet. The two idle chain-loops in the center are for short lengths. All manipulations are controlled by the overhead crane operator. The stands at either end of the device act as legs and hold the turning mechanism clear of the floor when not in use.

For further information circle No. 636 on literature request card, p. 48A and B.

Small Rolling Mill

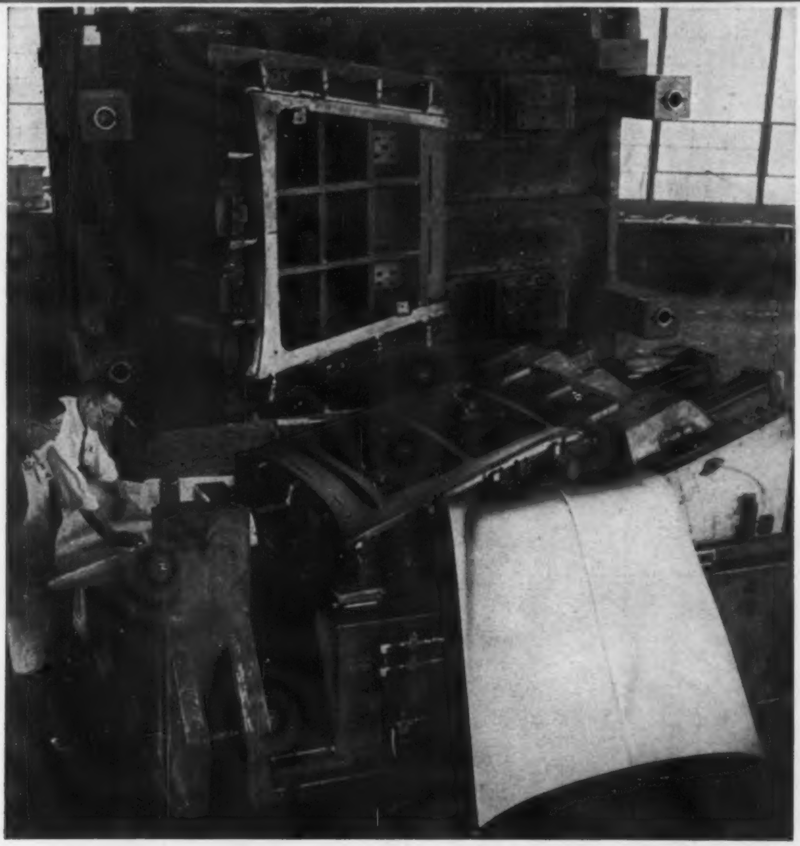
Loma Machine Mfg. Co. is producing a small rolling mill suitable for laboratory or pilot plant on conventional metals or for production (even in a gas chamber) of unconventional, active or nuclear metals. A completely self-contained unit encloses a 15-hp. variable speed motor and drive. Normally the housings are spaced for rolls 8 in. wide, although they can be moved apart for 10-in. rolls. Rolls can be 2-high (6 in. dia.) or 4-high (with 1½ in. work rolls in between). With the latter setup, strip can be cold rolled down to 0.001 in. gage. Roll necks are mounted in needle bearings of high precision. The hand-operated screw-down has a strength of 175,000 lb.

For further information circle No. 637 on literature request card, p. 48A and B.

Tool Steel Topics

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Distributor: Bethlehem Steel Export Corporation



Automotive Die, in 101 Sections, Made from Water-Hardening Steel

This huge die, made up of Bethlehem water-hardening tool steel (SAE W-2), trims an automobile hood. Made from tool steel furnished by Peninsular Steel Co., Detroit, the die was photographed recently at Republic Die & Tool Company, Wayne, Mich. It contains 44 composite sections, 34 wear plates, and 23 solid sections.

Bethlehem water-hardening steels were selected for this exacting application because of their good wear-resistance, easy machinability, and simple heat-treatment—plus ease of welding should repair become necessary.

Bethlehem water-hardening tool steels, because of their carefully controlled hardenability, provide economical service in applications calling for high shock-resistance. And with their highly selective carbon range, they have good resistance to wear, plus the toughness to withstand cold battering.

If you have any questions about the use of Bethlehem water-hardening tool steel, or any of our other popular grades, get in touch with your Bethlehem tool steel distributor. He's as near as your telephone.

Circle 855 on Page 48-A

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Here's How to Stabilize Gages

High-precision gages, commonly made of BTR tool steel (AISI Type 01), need a stabilization treatment if they are to maintain their accuracy for years. Otherwise expansion will eventually change dimensions outside of the permissible tolerance. These dimensional changes are in a magnitude of hundred-thousandths of an inch per inch, or smaller. Insignificant on ordinary tooling, they are important on precision gages.

The expansion which occurs over a period of time is due to the transformation of austenite retained during the quench for hardening. The object of the stabilization treatments is to transform the retained austenite during the treatment, so that none remains which could transform later on. This condition exists in all tool steel grades which can be hardened to Rockwell C 60 or higher.

The most common method for stabilizing high-precision BTR gages is: 1. Quench and temper in the normal manner to produce the desired hardness. 2. Rough grind. 3. Subzero cool to minus 100/120 F in refrigerator or dry ice. 4. Warm to room temperature and then retemper at original temperature. 5. Finish grind to size. 6. Repeat cycles of subzero cool followed by tempering five more times. 7. Lap or superfinish to size.

Sometimes it is possible to shorten this procedure, particularly if the design is such that there is little hazard of cracking. For example, the tools can be subzero cooled directly from the quench, with no interval at room temperature, followed by tempering and grinding. This will permit stabilization with only two additional cycles of subzero cool plus temper, but the disadvantage is that cracking may occur after quenching.

It is also possible to shorten the stabilization by cooling to minus 314 F in liquid air. This permits reducing the cycles of subzero cool plus temper to three instead of six.

THE MARK OF QUALITY

BARBER COLMAN

Impressor

PORTABLE HARDNESS TESTER

- Rapid testing — no setup
- Easy to carry and use
- Needs only space for hand

A portable hardness tester for brass, copper, aluminum, other soft metals, and plastics, the Barber-Colman Impressor is designed for fabricated parts and raw stock testing. Operating experience is not essential. The reading is instantly indicated on the convenient dial. No waiting, preloading, or separate measurements. Barber-Colman engineers will gladly recommend the most suitable model for your application. Write today for complete details.

BARBER-COLMAN COMPANY

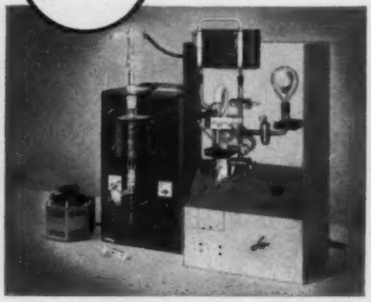
Dept. C, 1218 Rock Street, Rockford, Illinois

Circle 896 on Page 48-A

NEW HYDROGEN ANALYZER for metals

Leco®

3-10 Minute Analysis Time



Uses the hot extraction principle. Meets ASTM requirements (tentative procedure) of 1200°C or 2192°F operating temperature. Outgassing of a crucible is eliminated, due to a patented, inert, blank free susceptor. A unique device allows one sample to be loaded at a time, and removed from the system after extraction, without breaking the vacuum!

Write for literature today

LABORATORY EQUIPMENT CORP.

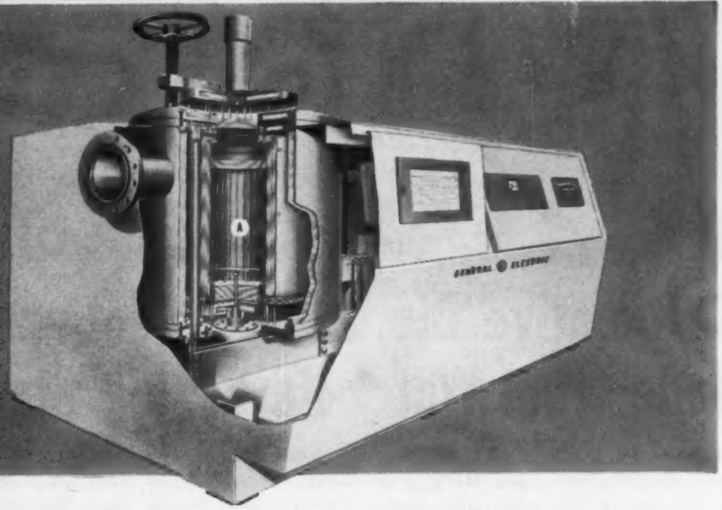
5063 Hilltop Road, St. Joseph, Michigan

Circle 897 on Page 48-A

HEAT

from General Electric

for critical treating in your laboratory or production line



NEW 4200 F Radiation Shield Vacuum Furnace from General Electric is extremely versatile. Will handle a wide range of heat treating, brazing, degassing, and sintering applications on metals like tantalum, titanium, zirconium, and ceramics. The complete furnace is factory-assembled in sturdy, attractive console unit. Each includes radiation shield furnace, vacuum system, furnace transformers, General Electric's stepless Reactrol* system, and full instrumentation. Installation is simple because system is pre-wired and pre-piped. And you get close control over wide range of heating and cooling cycles plus fast temperature response.

* Registered trade-mark of General Electric Co.

Large load space (A) handles shapes up to 10 inches high, 10 inches in diameter, weighing up to 50 pounds.

Ask your General Electric Sales Engineer for data on the complete line of G-E Vacuum Furnaces or write for bulletin GED-3793. General Electric Co., Schenectady 5, N. Y.

721-30

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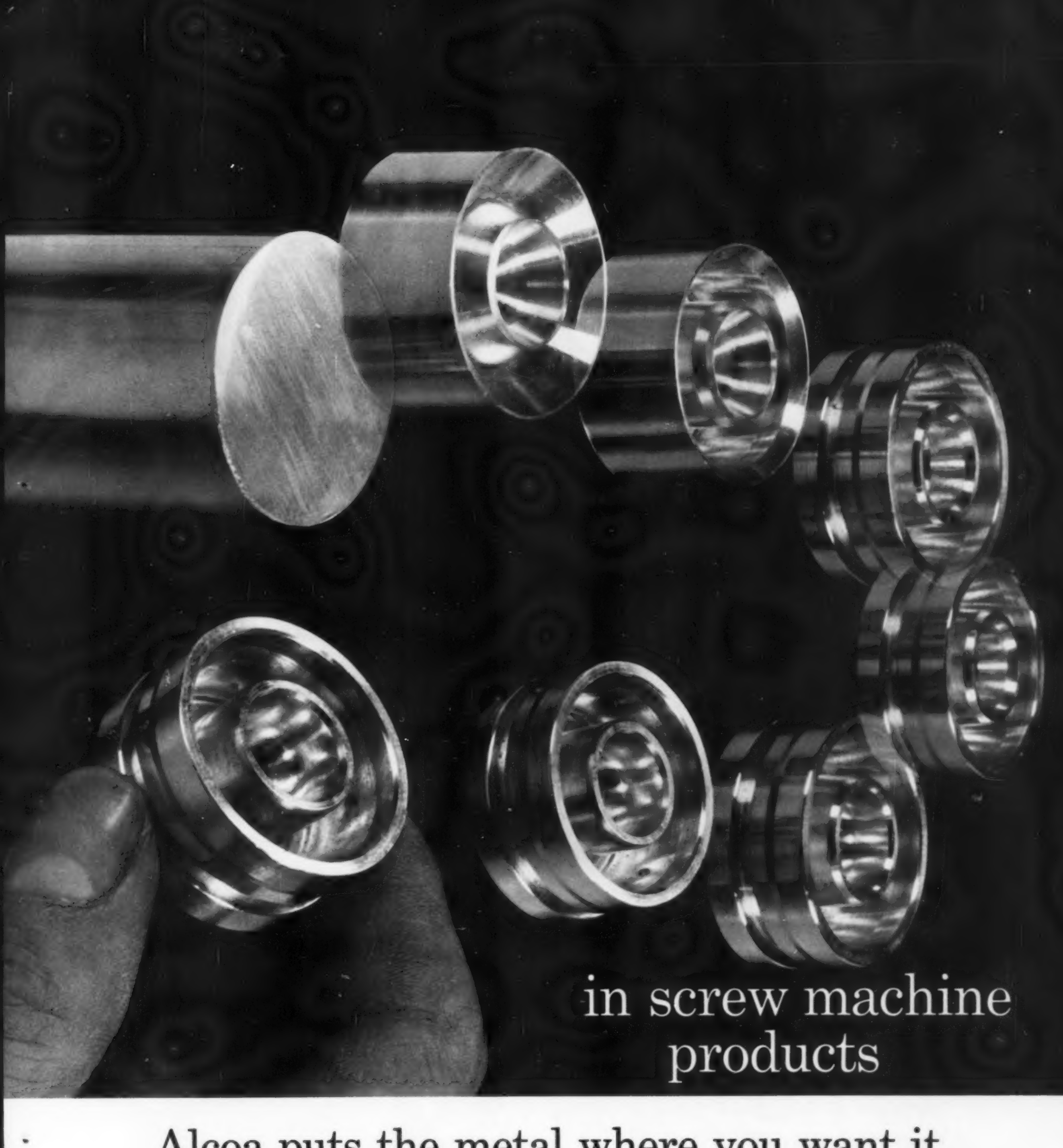
GENERAL ELECTRIC

Circle 856 on Page 48-A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For all your Metallurgical Microscope needs

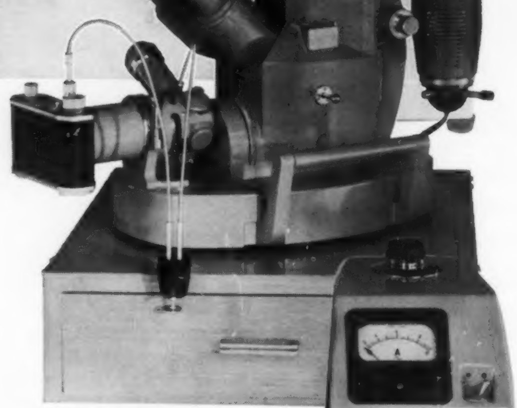
Now, there is a quality Elgeet-OLYMPUS inverted metallurgical microscope to do every job . . . from production line inspection to complex research projects. Elgeet . . . a new standard of quality, the most remarkable value on the market today.

Model ME

Inverted metallurgical and biological microscope complete with all optical equipment. **$556.00**

Model PMF

Metallurgical research microscope of the inverted "Le Chatelier" type, providing bright field, phase contrast, and polarized light illumination . . . all in one instrument. Complete with all optical equipment, built-in camera, and swivel base mount. **$2,465.00**



Model PMF

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"Quality is our watchword... Precision Engineering our constant goal"

Circle 858 on Page 48-A

Circle 859 on Page 48-A

Circle 860 on Page 48-A

NEW LITERATURE

Ferrous Metals

640. *Cr-Mo-V Steel*

Reprint from *The Vancoram Review* of an article entitled "Cr-Mo-V Steel for Service at Elevated Temperatures" is available from *Vanadium Corp. of America*

641. *Strong Stainless*

Technical booklet "AM 350 and AM 355" gives the properties and fabrication behavior of these two precipitation hardening stainless steels serviceable to 1000°F. and higher. *Allegheny Ludlum*

642. *Fine-Grained Steel*

New columbium-bearing carbon steel ("Fine-Grained GLX-W") has improved strength and toughness without impaired weldability. Data from *Great Lakes Steel*

643. *Special Alloys*

Literature presents advantages of special melting and casting processes known as "Mel-Trol," "VacuMeltrol" and "Consumet" for improving forgeability, finish and mechanical properties of high-perforance steels. *The Carpenter Steel Co.*

644. *"17-22-A" Steel*

This low alloy (less than 3% total) has 1000-hr. rupture strength of 65,000 psi. at 1100°F. It is readily forgeable, machinable, and weldable. Technical Bulletin 36B. *Timken Steel & Tube Division*

645. *"Stressproof" Steel*

LaSalle Steel Co. has issued a 12-p. engineering report on the beneficial effects of controlled copper additions to this type of steel, and the necessity of regulating all details of drawing and annealing practices.

646. *Ferrous Metallurgy*

"Basic Guide to Ferrous Metallurgy," a 16 x 21-in. wall chart, available from *Claud S. Gordon Co.*

647. *Stainless Sheet*

"Stainless Steel Handbook" states advantages of "MicroRold" sheet and strip delivered by Sendzimer cold reduction process to one third the A.I.S.I. tolerance. *Washington Steel Corp.*

Nonferrous Metals

648. *Tantalum Steel*

Bulletin 2:602 gives list of sizes, thicknesses and prices of tantalum sheet in stock for immediate delivery. *Fansteel Metallurgical Corp.*

649. *High-Temperature Alloy*

"René 41" (or General Electric's "TM") is described in Technical Bulletin No. 86. It is a vacuum-melted nickel-base alloy with superior properties in the 1200 to 1800°F. range. *Cannon-Muskegon Corp.*

650. *Phosphor Bronze*

Bulletin on "WRM" precision annealed phosphor bronze sheet and strip of uniformly fine grain, increased formability and fatigue life. *Waterbury Rolling Mills*

639. Heat Treatment

A 28-p. technical booklet directed to the metallurgical engineer, tool and die engineer, and others involved in heat treatment of steels. The booklet describes the derivation and meaning the T-T-T diagram and

gives information on such processes as step annealing martempering and austempering. It includes T-T-T diagrams for commonly used grades of S.A.E. toolsteels and is illustrated with photomicrographs and charts to clarify the text. *Uddeholm Co. of America*

651. *Copper-Nickel Alloy*

Information available about uses of "Cunisil-837," (97.5 Cu, 1.9 Ni, 0.6 Si) of 90,000 psi. ultimate strength and 40% the machinability of free-cutting brass. *American Brass Co.*

652. *Lithium*

Bibliography of 300 articles discussing effect of lithium additions to nonferrous metals available from *Foote Mineral Co.*

653. *Zinc*

Case history of dispenser using nine die castings of "Bunker Hill 99.99+% Zinc." *St. Joseph Lead Co.*

657. *Copper Alloy*

Bulletin describes copper alloy (about 10% aluminum, 4% iron, plus addition agents) of superior strength, shock and corrosion resistance available in plate 16 ft. wide by 30 ft. long. *Ampco Metal, Inc.*

658. *Cobalt*

A 60-p. compilation "Magnetostriction in Cobalt and Cobalt Alloys" includes data on many of the superior magnetic materials devised in the last 75 years. *Cobalt Information Center*

659. *High-Temperature Alloy*

Information available on "HOM," a high-nickel alloy for castings to operate in the 1800 to 2300°F. range, especially in oxidizing atmospheres. *The Duraloy Co.*

660. *Heat Treatable Copper Alloy*

Information about "Cunisil-837" (97.5% Cu, 1.9% Ni, 0.60% Si), a heat treatable alloy with 90,000 psi. tensile strength when precipitation hardened. *American Brass Co.*

661. *Tin*

A monthly publication called "Tin News" presents information on world supply and prices of tin as well as properties, uses, and manufacturing processes of tin and its alloys. *The Malayan Tin Bureau*

662. *Precious Metals*

Revised 10-p. brochure on solid and clad metals, electrical contacts, numerous plate products. *Metals & Controls Div., Texas Instruments*

663. *Brass*

Technical literature and case histories of "600 Alloy" of high strength, machinability and self-lubricating quality. Produced in press, hammer or cored forgings. *Mueller Brass Co.*

664. *Clad Metals*

Technical Data Sheet describing uses and advantages of duplex sheet and plate up to 42 in. diameter and 2.25 in. thick where core of steel or copper-base alloys are overlaid (one or both sides) with the required alloy for special service. *Bridgeport Brass*

665. *Clad Molybdenum Sheet*

Advantages of clad molybdenum are cited in a release from *General Electric Co.* Sheet 4 in. wide is available in thicknesses from 0.010 to 0.080 in., clad one or both sides with 0.001 in. of nickel or copper.

666. *Uses of Lithium*

"The Lithium Reactor" is a series of technical bulletins published at intervals by *Lithium Corp. of America*, containing news of latest developments in lithium chemistry and metallurgy.

Ask HEVI-DUTY

...The Brush Beryllium Company did...

and assured 'round-the-clock production of pure beryllium billets with HEVI-DUTY pit-type vacuum furnaces

Operating continuously, two Hevi-Duty pit-type vacuum furnaces produce high-purity beryllium billets. The framework over the furnaces supports the presses. Forged heat shields for the test models of Project Mercury's space capsule are being manufactured by Brush Beryllium from billets produced in these furnaces.

Two tons of high-purity beryllium billets are produced every week in two Hevi-Duty vacuum furnaces at The Brush Beryllium Company, Elmore, Ohio. These specially engineered, double pump vacuum furnaces operate continuously—24 hours a day; 7 days a week. They produce billets up to 40" diameter by 40" high. Brush Beryllium selected Hevi-Duty furnaces for continuous and simultaneous application of heat, vacuum and pressure. Beryllium powder is sintered at 1050° C. and subjected to 400 psi pressure inside the furnace retort. Three zones of control provide fast heating response, and assure the desired, uniform temperature. A 2000 micron vacuum is maintained at the high temperature, and during the cooling cycle.

Hevi-Duty offers standard bell or pit-type vacuum furnaces for operation to 2000° F. (2100° F. for intermittent service).

Hevi-Duty engineers can help you find the effective solution to most of your heat application problems. Whether it is a standard or special job, Hevi-Duty designs and builds the electric or fuel-fired furnace for most processing requirements.

ASK HEVI-DUTY
for more information about vacuum furnaces with operating temperatures to 2100° F.
Write for Bulletins 557 and 653A.

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HEVI-DUTY ELECTRIC COMPANY, MILWAUKEE 1, WISCONSIN

Industrial Furnaces and Ovens, Electric and Fuel • Laboratory Furnaces • Dry Type Transformers • Constant Current Regulators

Circle 861 on Page 48-A

Heat and Corrosion Resistant Materials

667. Haynes Alloys

"Blanketing the high-temperature field" is the claim made for 12 alloys produced commercially as castings or in wrought shapes, and described in literature by *Haynes Stellite Co.*

668. Industrial Concrete

"Lumnite" cement (calcium aluminate), applied by gun, cast, or trowel, protects hot areas in iron blast furnaces. Information from *Universal Atlas Cement*

669. Chromium Carbide

Bulletin CC1-P5 *(Union Carbide Metals Co.)* contains general data on chromium carbide. This refractory powder can be coated on articles such as turbine blades by flame spraying and electrodeposition.

670. Carborundum

Booklet and data sheets on "Super Refractories" giving data on short-time and sustained load tests at temperatures above 2150° F. *Carborundum*

671. Copper-Clad Laminates

Data sheets on paper-base laminates with copper foil or electrolytic plate, in overall thicknesses from 0.020 to 0.25 in. available from *Taylor Fibre Co.*

672. Insulation

Blocks formulated from asbestos and diatomaceous silica (called "Superex") described in IN-190A by *Johns-Manville*. 12 pages of design and technical data.

673. Graphite Heat Exchangers

Heil Process Equipment Corp. has information about heat exchangers using "Nocordal" graphite tubes 15 ft. long for maintaining sulphuric acid solutions for aluminum anodizing at proper operating temperature.

674. Insulating Firebrick

"K-20 IFB" is said to be 30% lighter than other 2000°F. insulating fire brick and Bulletin R-2-H tells how this is of advantage in annealing covers. *The Babcock & Wilcox Co.*

675. Superalloys

Handsome 32-p. booklet "Superalloys by Vacuum Induction Melting" presents equipment installed by *Kelsey-Hayes Co.* at its Metals Division, New Hartford, N.Y., and compares product with similar alloys air melted.

Nuclear Materials

676. Fuel Elements

Information available from *Babcock & Wilcox Co.* about design and construction of fuel elements for nuclear power reactors.

677. Current Rectifiers

8-p. bulletin describes "Unitron," a power conversion system for plating circuits based on a semi-conductor rectifier and transformer, with high power factor and efficiency. *I-T-E Circuit Breaker Co.*

678. Manipulators

Mechanical Division of *General Mills* has published booklets giving full details of manipulators—one for small hot cells, another of great versatility for alpha-gamma operations, and a third for heavy loads—100 lb.

679. Nuclear Metallurgy

Brochure describing comprehensive home-study course in reactor design, engineering, construction and operation. *Metals Engineering Institute*

680. Shielding Material

American Smelting & Refining Co. has data available on lead especially low in impurities which might be converted into radioactive isotopes when used as shielding material.

681. Cobalt 60

Information is offered by *Atomic Energy of Canada, Ltd.* on Co^{60} in pellets or slugs, up to kilocurie quantities or in "Weldcaps" (welded capsules) for radiography or source of radiation for any other purpose.

682. Mumetal

Data on "Mumetal" (77% nickel) which "soaks up magnetic fields like a sponge," and is an excellent shield for tape recorders and other items of electronic equipment. *International Nickel Co.*

683. Gamma Shield

Flyer shows how lead shot has unique qualities for shielding against gamma radiation. *National Lead Co.*

Tool Materials

684. Colloidal Graphite

Booklet "The Biggest Ounce of Protection" describes advantages of colloidal graphite as a lubricant for aluminum extrusions. *Grafo Colloids Corp.*

685. Solid Lubricants

30 brief field reports on successful applications of "M-55-Plus," in extreme-pressure forming dies and punches. It is "a collodial dispersion of sub-micron particles of MoS_2 in mineral oil." *Alpha-Molykote Corp.*

686. Cutting Solution

Bulletin A-9864 from *Oakite Products* explains "Formula 59" which does not get rancid and objectionable and yet has excellent lubrication, cooling and corrosion protection properties.

687. Toolsteel

Free machining, medium alloy toolsteel known as "Air-4" is presented in booklet by *Bethlehem Steel Co.* Hardening temperature is 1550°F.

688. Graphite Dispersions

Colloidal graphite dispersions, useful for lubricating forging dies, extrusion dies, or other high-temperature locations, as a dry film lubricant or as a parting agent. Descriptive literature from *Graphite Products Corp.*

689. Chem-Milling Stop-Off

16-p. pamphlet issued by *Eastman Kodak Co.* gives details about "Kodak Metal-Etch Resist" to protect specific areas from attack by etching or chemical milling.

690. Hot Work Toolsteel

Pamphlet "UHB Calmax" presents a Cr-W-Co air hardening toolsteel with superior performance in hot press dies, die casting dies, and extrusion dies. *Uddeholm Co. of America, Inc.*

692. Tool Steels

Allegheny Ludlum Steel Corp. has a publication list listing about 125 technical documents issued by them describing all phases of toolsteel manufacture, treatment and use.

693. Solid Film Lubrication

Information on method of surface preparation and application of molybdenum disulphide lubricant "Poxylube." *Poly Chem*

694. Forming Machines

"Plant Facilities Folder" illustrates standard radial draw forming and stretch relieving equipment but also a new series of high speed production formers. *The Cyril Bath Co.*

695. Wire Straighteners

Literature is available which describes a new series of wire straighteners (has sets of five to 11 rolls set at right angles). Rolls are grooved to handle round, flat or wire of special shapes. *Durant Tool Co.*

696. Calcium Stearate

Bulletin 42 explains "Flexichem CS," an impalpable powder of superior covering power and lubricity for metal powder compacts, and as a mold release agent for resin-coated sand. *Swift & Co.*

697. Hacksaws

Service data, indicating that "Silver Streak," a high speed steel blade precisely heat treated, outlasts conventional blades two to one. *Atkins Saw Division of Borg-Warner Corp.*

698. Chemical Milling

Bulletin 200 presents "Anocut HCS-59," a machine and method for electrolytic machining of holes or depressions of any shape in very hard and very tough metals or alloys. Complete with recovery system. *Anocut Engineering Co.*

699. High-Speed Saws

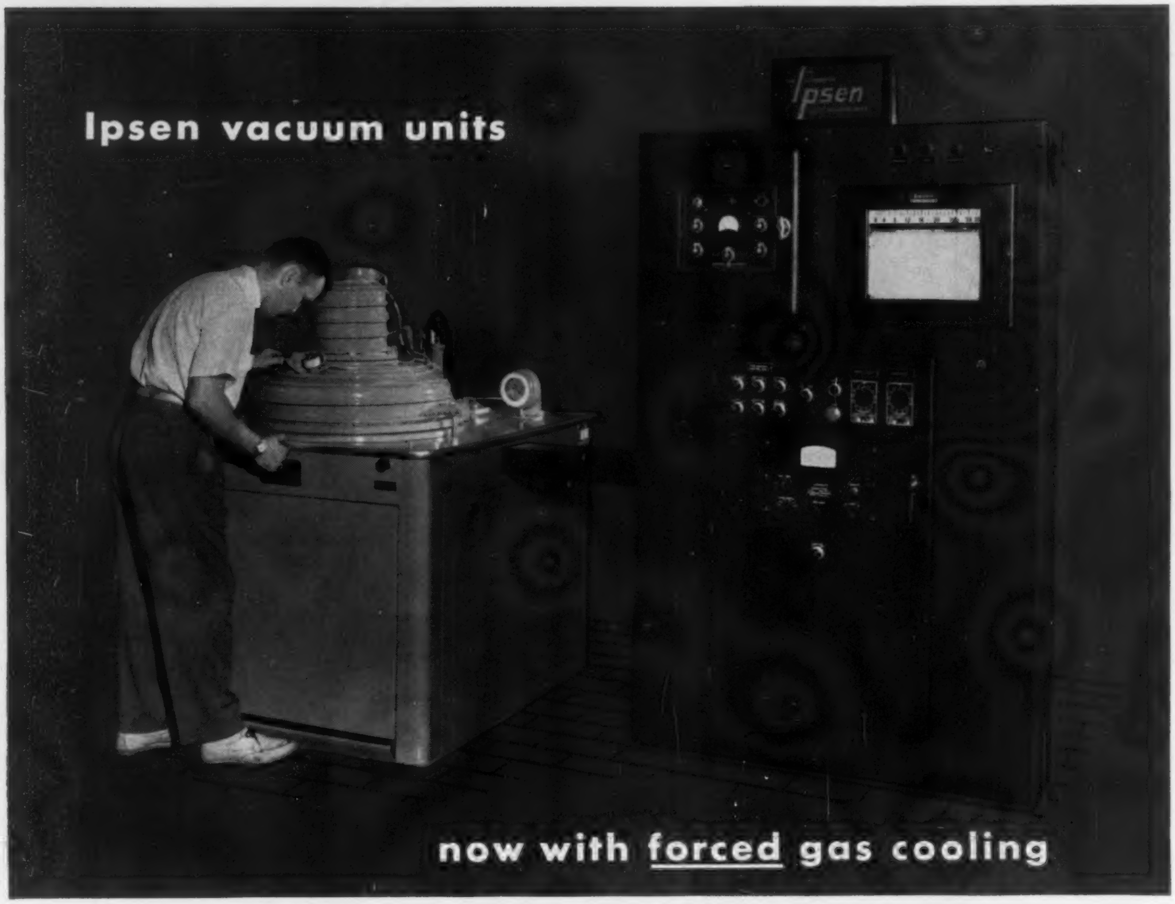
8-p. catalog of "Zephyr" band sawing machines with 36-in. throat. Band may be given velocity as high as 15,000 ft. per min. and can cut stainless steel 1 in. thick; nonferrous metal and nonmetallics as fast as they can be fed. *The Do-ALL Co.*

700. Punch and Die Design

24-p. pamphlet comprises a design and maintenance manual for those who desire greater life and accuracy of punches, dies, retainers, hold-downs and strippers. *Butler Mfg. Co.*

701. Shear Guard

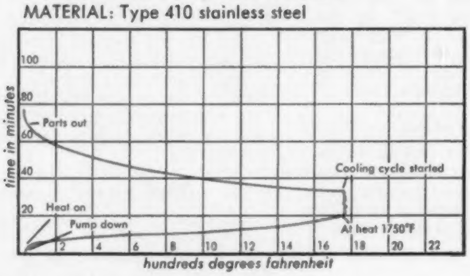
Data on transparent plexiglas guards which can be affixed to metal squaring shears with 30 or 36-in. throat, guard the operator and yet not obstruct his view of cutting blade or template marks. *Brett-Guard Corp.*



Ipsen vacuum units with *fast gas cooling* now offer a safe and economical method for bright hardening and annealing of stainless steels, high-speed steels, tool steels, and high temperature alloys; also, sintering and brazing of high temperature alloys!

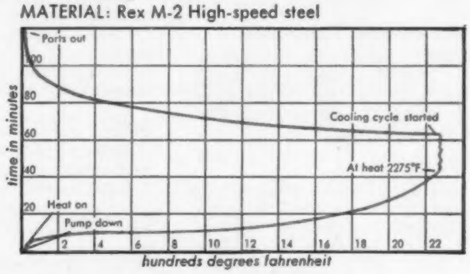
Here are typical examples of performance by the VVFC-1014-E furnace pictured above:

PARTS: Aircraft quality screw fasteners
MATERIAL: Type 410 stainless steel



COMPLETE TIME CYCLE: 1 hour 8 min.
RESULTS: Rockwell C 42-43
APPEARANCE: Exceptionally bright

PARTS: Boring bars
MATERIAL: Rex M-2 High-speed steel



COMPLETE TIME CYCLE: 2 hours 10 min.
RESULTS: Rockwell C 64-66
APPEARANCE: Exceptionally bright

A complete line of standard vacuum units is available. Also, vacuum facilities are available in which processing, testing, and analysis can be made to recommend the proper equipment for your parts. For detailed information contact Ipsen Industries, Inc.

AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • 723 SOUTH MAIN STREET • ROCKFORD, ILLINOIS

Circle 862 on Page 48-A

Industrial Heating

705. *Sintering Furnaces*

Furnaces for production sintering of compacts for precision parts detailed in folder from *Harper Electric Furnace Corp.* Preheating chamber operates at 1500, sintering up to 2400°F. depending on make-up of work, and gradient cooling chamber.

706. *Gas Burners*

Complete "Buzzer" catalog presents gas burners and furnaces for heat treating, melting and soldering. Bench type furnaces up to 2000°F.; atmospheric and pot furnaces up to 1650°F. *Charles A. Hones, Inc.*

707. *Brass Annealing*

A furnace for annealing continuously brass strip at speeds up to 200 ft. per min., uniformly edge to center, by virtue of unprecedented velocity of convection currents in the furnace atmosphere. Bulletin SC-182, *Surface Combustion*

708. *Precise Thermocouples*

Data on specification 3-G-178 ("Chromel - Alumel") thermocouples accurate to half the standard tolerances, and specification 3-G-170, whose accuracy is guaranteed to ±5°F. over range from 1000 to 2000°F. *Hoskins Mfg. Co.*

710. *Rivet Coolers*

Specifications on four models of sub-zero chests of 1.5 to 6.5 cu. ft. capacity. No liquid coolant is required for temperature from −30 to −140°F. depending on model. *Revco, Inc.*

711. *Heat Treating Units*

Advantages of "Light-Weight" heat-treating units—prefabricated tubes, return bends—described in booklet by *The Pressed Steel Co.*

712. *Continuous Heat Treating Unit*

Diagrams and complete details of pusher type of furnace, four zoned (entrance, treating, soaking, cooling) all under forced circulation of prepared atmosphere. *Ipsen Industries, Inc.*

713. *Cold Chambers*

Literature on sub-zero chambers—complete units similar in appearance to a kitchen refrigerator—mounted on skids or casters. *Cincinnati Sub-Zero Products*

714. *Heating Equipment*

Literature describing large and small ovens, atmosphere generators, melting pots, and billet heaters. *Sunbeam Equipment Corp.*

715. *Heating Furnaces*

20-p. bulletin No. 591 describes gas-fired, oil-fired and electric furnaces for heat treating any product by any process, capacity large or small. *The Electric Furnace Co.*

716. *Induction Heat Treatment*

Bulletin entitled "Typical Results of 'Tocco' Induction Hardening, Heat Treating and Annealing," published by *The Ohio Crankshaft Co.*

717. *Quenching Unit*

Closed system circulates quenching fluid through heat exchanger (air cooled) automatically maintaining tank at pre-set temperature. Bulletins 120 and 132. *Niagara Blower Co.*

718. *Heat Treating Stainless*

American Gas Furnace Co.'s Catalog 8A presents a shaker hearth furnace with alloy muffle for heat treating individual stainless parts in cracked ammonia atmosphere at the rate of 100 lb. per hr.

719. *Convertible Furnace*

Bulletin F-212 sets forth advantages of several accessory groups which easily convert a basic furnace unit into a device for a particular job, ranging from martempering below 1000°F. to melting a refractory metal. *Thermo Electric Mfg. Co.*

721. *Billet Heater*

Production of more and better aluminum extrusions from billets heated by induction, with data on costs, is described in Bulletin 598 from *Ajax Magnethermic Corp.*

722. *Stress Relieving*

Equipment for "simplified and programmed" stress relieving of parts or assemblies, large or small, with 400-cycle induced currents. *Hobart Brothers Co.*

723. *Trays*

Electro-Alloys Division can furnish a number of case histories showing how proper design of grids, having in mind thermal fatigue, will increase service life many fold.

724. *Custom Designed Furnaces*

Pacific Scientific Co. has literature about custom designed heat treating furnaces, such as one which introduces a sizing tool into a casing just prior to the quench.

725. *Chill Treatment*

Case histories of chill treating (−130 to −150°F.) by such firms as Bosch Arma, Raytheon, Hoover, N. Y. Air Brake, for stabilization and toughening of steel parts available from *Harris Refrigeration Co.*

726. *Environmental Chambers*

Brochure entitled "Controlled Atmospheric Conditions" about environmental chambers and low-temperature freezers available from *Webber Mfg. Co.*

727. *Hump-Type Furnace*

A continuous furnace without muffle for heat treating, brazing or sintering (maximum temperature 2200°F.) in prepared atmosphere is described in Bulletin GED-3990. *General Electric Co.*

728. *Induction Heating Unit*

Bulletin 5910 presents information on new high-frequency unit introduced by *C. I. Hayes,* useful for, among other things, selective hardening, tempering and annealing of tool-steels. The 30-kw. unit is completely enclosed in a single cabinet.

729. *Convection Ovens*

Brochure No. 1960 describes "Power-O-Matic 60" series of ovens, electrically heated. The power supply is governed by a new device by Westinghouse which is infinitely proportional and requires no switches, so as to give unusually constant temperatures. *Blue M Electric Co.*

730. *High-Frequency Heaters*

Catalog gives details of electric tube generators of outputs ranging from 1 kw. to 100 kw., and of spark gap converters from 2 kw. to 30 kw. *Lepel High Frequency Laboratories*

731. *Pusher Unit*

Bulletin P-59 gives details about pusher heat treating units, each of the zones having forced circulation silicon carbide skid-type hearths. *Ipsen Industries*

732. *Atmosphere Dryer*

Revised catalogue shows "Dynadryer" automatic driers of air or prepared gases using molecular sieves to supply an oil-free and dust-free product with dew point below −100°F. *United States Dynamic Corp.*

733. *Electrodes for Salt Baths*

Bulletin 151 is an 8-p. brochure describing salt bath furnaces for both high and low temperature and the advantages of "continuing" electrodes for heating elements. *Lindberg Engineering Co.*

734. *Treating Aluminum*

Melting, holding and heat treating furnaces for aluminum and its alloys, billet preheaters, homogenizing and aging ovens explained in Bulletins 653, 591 and 159. *Hevi-Duty Electric Co.*

Cleaning and Finishing

739. *Batch Cleaner*

Cleaning on-the-spot can be done by bringing one or more "Surg-A-Flow" units to any place in the production line. The work tray is operated by a vertical air cylinder. No electrical connections needed except where heating is necessary. Information from *Alvey-Ferguson Co.*

740. *Solvent Stabilizer*

36-p. Bulletin on "Nialk Trichlor," a stabilizer which stays with the solvent, also includes information on basic types of vapor degreasers, operating procedures and trouble shooting. *Hooker Chemical Corp.*

741. *Caustic-Free Cleaners*

Data sheets on four caustic-free cleaning compounds tailored to the requirements of four basic processes: hot power washers, cold power washers, hot soak tanks, and cold soak tanks. *E. F. Houghton & Co.*

742. *Vibratory Finishing Machine*

Data Sheet C-35-S covers "Model VT-72 Vibrasheen" with 2½ cu. ft. capacity for deburring or burnishing small parts in shorter time than ordinary barrel finishing. It vibrates at 3380 cycles per min. *King-Seeley Corp.*

743. *Finishing Equipment*

Loose-leaf binder of sheets descriptive of machinery for washing, cleaning, spraying, coating and baking metal parts in production. *Pennsalt Chemicals*

744. *Nickel Plate*

Technical brochure on "NC" bright nickel process, suitable for buffed or matte surfaces, describing both and its operation. *Seymour Mfg. Co.*

746. *Blast Tables*

"Types LK and LM Rotoblast Table-Rooms" described in 12-p. bulletin by *Pangborn Corp.* designed to clean castings or weldments up to 10 ft. wide and weighing as much as 6 tons.

747. *Liquid Cleaner*

"Kelite Formula 28" is explained in a bulletin by *Kelite Corp.* It removes grease, dirt and carbon desposits at room temperature without heat, fume or fire hazard.

748. *Duplex Chromium Plating*

Technical data sheets set forth methods and materials for depositing an underlying layer of crack-free corrosion-resistant metal and then an overlay of crackled pattern of hard wear - resistant metal. *Metal & Thermit Corp.*

749. *Metal Abrasives*

Data on "Malleabrasive" shot or grit, properly selected and sized for the individual application. *Globe Steel Abrasive Co.*

750. *Degreasers*

Bulletin 655 illustrates multi-stage equipment in various sizes for soaking in warm solvent, degreasing in vapor, scrubbing in boiling solvent, cooling, and vapor rinsing. *Ramco Equipment*

751. *Uniform Ni Plating*

"Kanigen" is described in Bulletin 258. It is said to plate uniformly regardless of contours of the part. Final machining before plating and no subsequent cleanup. *General American Transportation Corp.*

752. *Finishing Machine*

"Vibratron" jiggles the work while immersed in abrasive rather than tumbles it in a rotating barrel. *Roto-Finish Co.*

753. *Wet Blast Unit*

Stainless steel "Consol-Matic" unit is designed for cleaning small parts. It has one loading and one unloading bay; air-driven guns blasting fine (5000 mesh) abrasives operate a preset time. *Pressure Blast Mfg. Co.*

754. *Chemicals*

File folders on process chemicals for the metal finishing industries (chromate coatings, clear coatings, brighteners, plating chemicals). *Allied Research Products*

755. *Ultrasonic Cleaners*

Bulletin S-236 describes modular cabinet-type ultrasonic cleaning systems with cleaner, filter, heater, recirculator, rinsing and drying units. *Branson Ultrasonic Corp.*

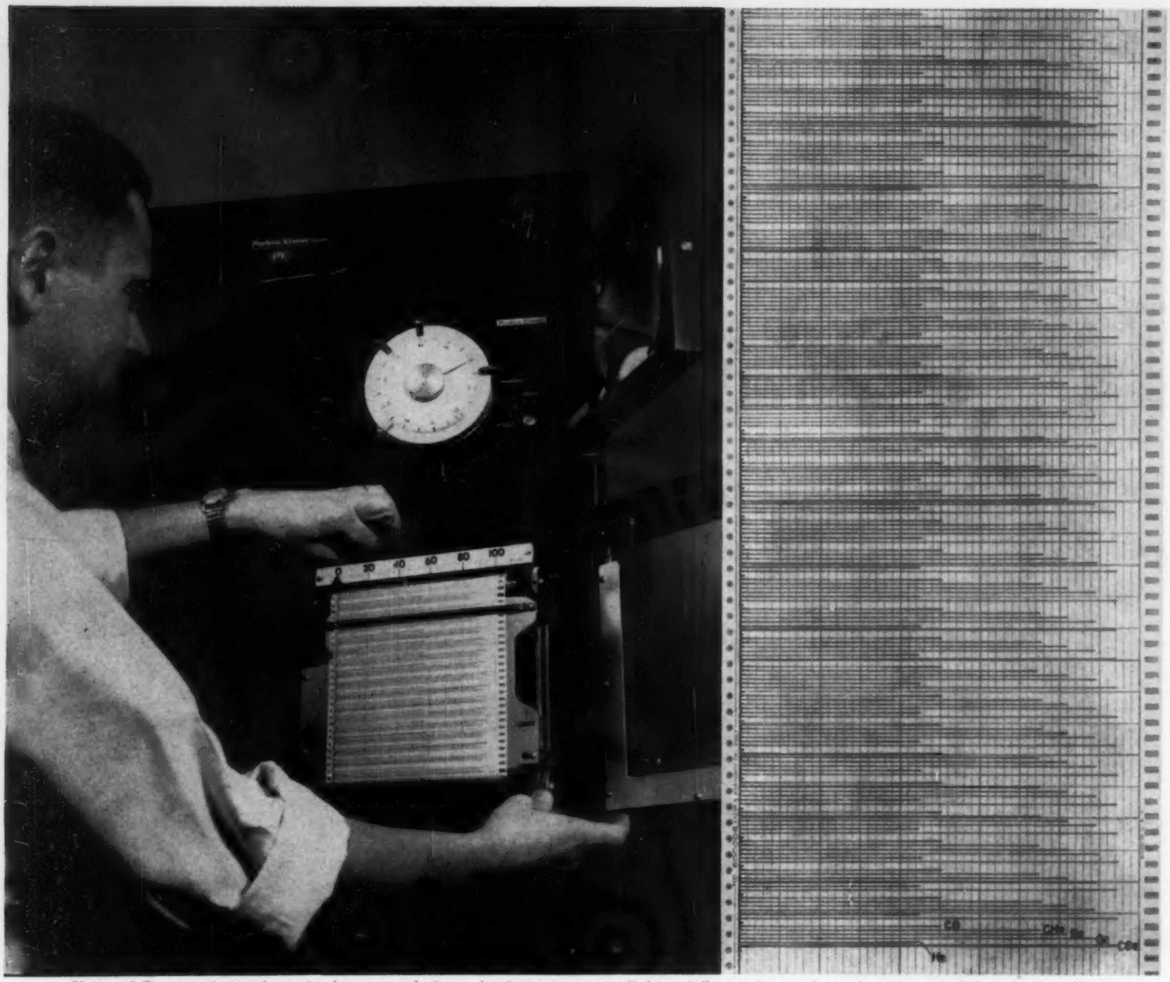


Photo of Furnace Atmosphere Analyzer panel shows (top) programmer dial, and (bottom) recorder unit with typical bar-chart cyclic record of four-component analysis. All other operating components, connections, etc., are in back of panel on rugged caster-mounted framework. At right, Furnace Gas Analyzer chart record shows cyclic measurement of 6 components of furnace atmosphere.

NEVER BEFORE A FURNACE GAS ANALYSIS SO COMPLETE, FAST, ACCURATE

With the new Perkin-Elmer Furnace Atmosphere Analyzer, you can analyze furnace atmospheres with all the accuracy, speed and completeness needed for precise control. The analytical information provided by this new instrument gives you product quality insurance never before possible — cuts operating costs and reduces rejects.

The Perkin-Elmer Analyzer automatically records the volume percent of each of 4 components. You can analyze for the usual gases—O_2, CO, CO_2, CH_4—or for other components, depending on your requirements. On special order, too, you can have an instrument designed for 5 to 8 components. From this detailed, accurate analysis, the operator can easily maintain the proper composition of the atmosphere.

Whether your operation involves heat treat furnaces, gas generators, kilns or other combustion devices, you'll find the Furnace Atmosphere Analyzer introduces an entirely new degree of control. Unlike single-component analyzers, it analyzes all key components without interference from other components. And unlike chemical analysis methods, it requires no operator attention.

Complete details on this rugged, plant-tested instrument are given in a booklet "New Perkin-Elmer Furnace Atmosphere Analyzer." Write for your copy today. Our address: 925 Main Avenue, Norwalk, Conn.

INSTRUMENT DIVISION
Perkin-Elmer *Corporation*
NORWALK, CONNECTICUT

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Welding and Joining

758. *Copper Brazing*

"Design for Controlled Atmosphere Copper Brazing" is a 24-p. handbook for designers, engineers and manufacturers which discusses "do's and dont's," inspection methods, and contains a variety of technical information. *Fabriform Metal Products*

759. *Nickel-Silver Welding Rod*

Versatile rod to use with oxy-acetylene blowpipe and for joining all carbon steels, toolsteels, cast irons, stainless steels, nickel and nickel alloys. Information from *Air Reduction Sales Co.*

760. *Arc Welding Supplies*

Complete catalog of head shields, goggles, cleaning tools, electrode holders, clamps, cables and protective clothing. *Hobart Brothers Co.*

761. *Cable Connector*

Bulletin W-32 describes a connector for welding cables having a new locking action—joins with a twist of the wrist. No springs, catches or snaps. *Ampco Metal, Inc.*

762. *High Temperature Braze*

Data sheets on five different high-temperature brazing alloys, strong and ductile, capable of joining refractory alloys, and operating from 500 to 2000°F. *Handy & Harman*

763. *Diesel-Electric Welder*

Complete details and engine specifications of d.c. welder (50 to 350 amp.) driven by 3-cylinder direct injection diesel engine. *Miller Electric Mfg. Co.*

764. *Miniature Soldering Iron*

About the size of a fountain pen, and heating element and connections assembled as easily as a battery can be put into a flashlight. Bulletin by *Caig Laboratories*

765. *Combination Welders*

Twin a.c.-d.c. combination welders (portable) are available in two sizes. Complete specifications from *Miller Electric Mfg. Co.*

766. *Silver Alloy Brazing*

Handy and Harman say of Bulletin 20: "There is no beter introduction to the simplicities of silver alloy brazing than this piece of literature," to quote their release.

767. *Reuse of Flux*

Lincoln Electric Co. is making a funnel through which flux recovered from previous use in submerged arc operation is passed. The funnel contains three alnico magnets which remove mill scale, metal spatter and grindings.

768. *Multi-Arc Welding*

72-p. "Guide to Better Welding." It covers technology, economics and other aspects of multi-arc welding. *J. B. Nottingham & Co.*

Inspection and Control

774. *Fatigue Testing Machine*

Bulletin explains a system of non-resonant components suitable for imposing loadings ranging from 12,000 to 300,000 lb., strokes up to 6 in., and of variable frequency. Useful for testing assemblages, large and small. *Riehle Testing Machines*

775. *Oscilloscope*

Allen B. DuMont Laboratories' Model 425 oscilloscope has devices where time and amplitude are read directly by numerals on the front panel. Also the various functions such as tube, amplifier, plug-ins are self-contained in modules which are easily replaced as a unit.

776. *Hardness Tester*

Bulletin CRS60 gives data on motorized indentation hardness tester, capable of regular and superficial Rockwell tests in a single machine. *Torsion Balance Co.*

777. *Diffraction Equipment*

Bulletin on complete X-ray diffraction unit including generator, two powder cameras, one flat camera, a stereo-microcamera. Other attachments available. *Radio Corp. of America*

778. *Basic X-Ray Techniques*

Wall chart diagrams and describes briefly 10 basic uses of X-ray equipment in metallurgical research, inspection and control. *Philips Electronic Instruments*

779. *Flow Meters*

Bulletin 110 concerns auxiliaries for adapting a directing-reading device for measuring flow of liquids or gases to various types of indicators, recorders, annunciators or punched tape. *Brooks Rotameter Co.* Bulletin 150 also describes Rotameters for corrosive services.

780. *Metallographs*

Catalog 2-Z lists specifications for completely equipped instrument with all necesary accessories in a single unit. *Unitron Instrument Division of United Scientific Co.*

781. *Stereo-Micrography*

Information folder on "Cycloptic" equipment whereby 35-mm. Graflex stereoscopic camera fits eye pieces. Viewer, also. *American Optical Co.*

782. *Hardness Testers*

Bulletin CRS 60 presents many motorized "Kentrall" hardness testers for regular and superficial Rockwell tests. *The Torsion Balance Co.*

783. *Indentation Testers*

Full line of equipment and accessories for hardness testing, manual, power and automatic, set forth in Catalog RT-58 by *Wilson Mechanical Instrument Division*

784. *Temperature Crayons*

Information on "Tempilstiks" (temperature indicating crayons). Eighty different ratings from 113 to 2500°F. *Tempil Corp.*

794. *Ultrasonic Gage*

Thickness of metal, glass, plastic sheets or layers may be measured with portable (5 lb.) generator, transducer and head phones to accuracy within 5%. Bulletin A-200. *Branson Instruments, Inc.*

795. *Tensile Testing*

Complete information on tensile testing equipment and methods of high precision, including modern extensometers, available from *Instron Engineering Corp.*

796. *Brinell Machine*

Detroit Testing Machine Co. will be glad to send details about Model DHL, a Brinell machine with a stationary table but test ram with a long stroke.

797. *Dyanomometers*

Manual of applications and description of line of 15 rugged dynamometers with capacities up to 200,000 lb. They are direct reading and by special fixtures read loads in torque, tension, compression or weight. *W. C. Dillon & Co.*

798. *Research Equipment*

Interference microscopes, particle counters, dilatometers and thermo balances described in a series of data files. *Cooke, Troughton & Simms*

799. *Moisture Analyzer*

Complete information available on "Model W Electrolytic Moisture Analyzer," sensitive to 1 part per million of water in a wide variety of gas streams. *Manufacturers Engineering & Equipment Corp.*

800. *Spring Tester*

Hand operated spring tester of high precision is described in bulletin by *The Carlson Co.* Capacity is 1 oz. to 225 lb.; spring lengths up to 12 in. and 4 in. diameter are accepted. 600 tests per hour can be made.

801. *Hardness Testers*

Units for making all types of Rockwell hardness tests described in reference book by *Clark Instrument, Inc.*

802. *Proving Ring*

Pamphlet describes calibrated rings for proving the accuracy of testing machines, one type where the load is indicated by a dial pointer and the other uses a ruled scale and filar microscope. *Steel City Testing Machines*

803. *Radiation "Pyrometer"*

Range from zero to 200°F. achieved by "Velotron" pyrometer systems. Data sheets describe automatic compensation for ambient temperature. Measures temperatures of stationary or moving objects. *The Bristol Co.*

804. *Surface Finish Control*

Pocket-size 12-p. reference manual explains the "Surfindicator," a gage for finish control in production. Also chart to convert arithmetical average to root means square overages. *Brush Instruments Division of Clevite Corp.*

805. *Collimator*

Literature completely describing a photo-electric "Microptic Auto-Collimator" is available from *Engis Equipment Co.* It can be used for precise testing of angles, circular divisions, straightness, flatness and alignment.

806. *Conversion Factors*

A wall chart has been published by *Precision Equipment Co.* giving in handy form the factors for converting such things as atmosphere into kg. per sq. cc., cu. ft. to liters, and so on.

807. *Hardness Tester*

Kentron Micro Hardness Tester can easily vary load from 1 to 1000 g. and indenter from Knoop to Vickers. A bench type, research instrument. Bulletin K-59. *Torsion Balance Co.*

808. *Spectrographic Equipment*

6-p. bulletin on theory and operation; direct reading spectrometers; direct reading spectrograph for research. *Baird-Atomic, Inc.*

809. *Control Device*

The "Regohm Transducer" can be actuated by a lever movement of 0.0001 in. and control electrical input of 250 watts. Can be operated by slight bending of a bimetal, bellows movement or elastic expansion. *Electric Regulator Co.*

Production and Casting

810. *Compressor*

Single-stage compressor for air or gas is described in Bulletin GG-5H from *Joy Mfg. Co.*, to deliver up to 1630 cu. ft. per min. at 125 psi.

811. *Potentiometers*

Data sheets give details about millivolt potentiometers available for many temperature ranges and high accuracy. *Leeds and Northrup*

812. *Bagged Alloys*

Folder with the above title issued by *Union Carbide Metals* gives specifications for eleven varieties of alloying additions, bagged to eliminate losses and to help keep the furnace room clean.

813. *Vacuum Furnace*

Data on Kinney 5 to 50 lb. vacuum induction furnace, complete with pumps and controls. *Kinney Vacuum Division of New York Air Brake Co.*

814. *Vanadium Additions*

Booklet entitled "Grainall and Its Uses" *(Vanadium Corp. of America)* shows how this addition agent refines steel's grain size, intensifies hardenability, and prevents ruptures during hot forming.

815. *Rotary Compressor*

Rotary air compressors (20, 25, or 40 hp.) for 100-lb. service are described in Bulletin E-269 of *Davey Compressor Co.* They are quiet, require no foundation or vibration dampers.

816. *Vacuum Pumps*

Consolidated Vacuum Corp.'s Bulletin P8-20 illustrates high-speed Roots pumps which operate without pump fluid, steam or sealing oil and thus do not contaminate from back streaming.

Titanium and Zirconium Alloys

produced by TAM in a practical range of compositions...

High Carbon FCT
Effective deoxidizer and cleanser for medium and high carbon steels.

Medium Carbon FCT
Deoxidizer and cleanser with less increase in carbon content of the steel.

Carbortam*
FCT Alloy with boron for hardenability. Also used as deoxidizer for steel castings.

40% & 25% Low Carbon Ferro Titanium
Used as carbide stabilizer in austentic stainless steels, as source of residual titanium content in other alloy steels. Also a constituent of weld rod coatings.

Foundry Ferro Titanium
Deoxidizer and grain refiner for steel.

Manganese Titanium
Deoxidizer in high grade steel or non-ferrous alloys.

Nickel Titanium
Source of titanium for addition in nickel base alloys.

Silico Titanium
Titanium source in cast iron and cast steel.

Ferro Aluminum Zirconium Alloy
Zirconium source in special alloys.

Titanium Carbide
Component in sintered cutting tools, jet engine parts, refractory material, abrasives.

Zirconium Cyanonitride
An intermediate for the production of zirconium tetrachloride and process metallurgical applications.

Zirconium Aluminum
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Magnesium Zirconium Master Alloy
Efficient alloying of magnesium with zirconium. Available in 35% and 50% zirconium content.

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*REG. T. M.

Circle 918 on Page 48-A

817. *Rolling Mills*

Descriptive material on rolling mills —specifically 140-in. 4-high reversing mill and vertical edging mill for slabs and plates. *Mesta Machine Co.*

818. *Alloying Metals*

Reports on "Precision Melting Stock" (shot or granular) for formulation of castings of superalloys. *Wai-Met Alloys Co.*

819. *Slitters*

80-p. manual "Slitting Equipment" promotes idea that special equipment will pay for itself if as little as 100 tons are handled per month. *The Yoder Co.*

Parts, Forms, Shapes

820. *Thermostatic Bimetals*

Booklet, "Successful Applications of Thermostatic Bimetal," presents many temperature-actuated devices and much engineering and design data. *W. M. Chace Co.*

821. *Custom Fabricator*

24-p. Bulletin 900-P5 illustrates large variety of important custom jobs in stamping, upset forging and rotoforming. *Commercial Shearing & Stamping Co.*

822. *Tubular Shapes*

A series of data folders giving sizes of welding fittings and forged flanges in nominal sizes from 2 to 24 in. Technical Bulletins FDC 252 to FDC 275. *Babcock & Wilcox Co.*

823. *Weld Nuts, Screws and Pins*

Stock Parts Catalog 60 shows complete line of steel fasteners suitable for resistance welding to other parts using high - speed semi - automatic equipment. *Ohio Nut & Bolt Co.*

824. *Magnesium Fabrications*

Technical data and literature is available from *Brooks & Perkins* on light alloys (magnesium, titanium, magnesium-thorium alloys) for aircraft, satellite and missile assemblies.

825. *Headed Copper Parts*

Paper on economy and methods of cold heading copper and its alloys, either as primary or secondary fabrication operation. *John Hassall, Inc.*

826. *Investment Castings*

48-p. bulletin is a "Practical Guide," showing typical applications of investment castings by industries, specifications of standard alloys, ferrous and nonferrous, design information and manufacturing procedure. *Arwood Precision Casting Corp.*

827. *Stainless Steel Tubing*

Information about seamless and welded tubing in a variety of analyses and composite construction, as well as hints on fabrication, and data on corrosion resistance. 38-p. booklet from *Allegheny Ludlum Steel Corp.*

828. *Seamless Steel Tubing*

Complimentary copy of "Ostuco Steel Tubing" will bring information about tubes of precise shape and size and correct physicals, either for use as such or as stock for further working. *Ohio Seamless Tube Division of Copperweld Steel Co.*

829. *Stainless Steel Filters*

Bulletin M-212A gives specifications of stainless steel filters stocked by *Pall Corp.*, and discusses generally the properties of "porous" stainless steel.

830. *High-Strength Bolts*

Especially designed for aircraft, a new "LWB 22" series of fasteners having 220,000 psi. minimum tensile strength and can endure 80,000 psi. loadings 10,000,000 times without fatigue failure. Form 2531, *Aircraft Missile Division, Standard Pressed Steel Co.*

831. *Wear Resistant Surfaces*

Bulletin PS describes "Chromallizing," a process whereby hardening elements are diffused into surface layers, giving high wear resistance and considerable oxidation resistance. Leaflet No. 40 on design is also available. *Chromalloy Corp.*

832. *Extruded Shapes*

Number 3, Vol. 24 of *Harper Bolt News* describes alloys regularly extruded, gives hints on design of new cross sections, size limitations and tolerances, and hints on economical use. *H. M. Harper Co.*

834. *Metal Mesh Belts*

130-p. reference manual contains information on conveyor belts for moving small parts or assemblies through sintering, brazing, annealing, quenching or washing operations. *Cambridge Wire Cloth Co.*

835. *Self-Locking Nut*

Bulletins 3002 and 3 describe a self-locking nut with aluminum body and spring temper stainless steel wire for threads, with special configuration in the coil to exert uniform radial pressure. *Waltham Precision Instrument Co.*

836. *Quality Steel and Parts*

Illustrated booklet, "Quality Control at Standard," details laboratory facilities and liaison with shop superintendents and top management at *Standard Steel Works Division of Baldwin-Lima-Hamilton.*

837. *Meehanite Castings*

Bulletin 43 by *Meehanite Metal Corp.* lists the mechanical and physical properties, machinability rating, etc., of six engineering types of this specialized cast iron, and of six varieties suitable for working at temperatures up to 1650° F.

838. *Heavy Forgings*

Bulletin NH-1058 describes melting, forging and nitriding equipment capable of making large items such as crankshafts, piston rods, drive shafts, marine couplings and heavy machine parts. *National Forge Co.*

839. *Mechanical Tubing*

Information about seamless tubing in a large range of sizes, finishes and heat treated conditions (even special shapes and prefabricated forms) is given in Bulletin TB-361. *Babcock & Wilcox Co.*

Circle 872 on Page 48-A

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CLEANING AND FINISHING EQUIPMENT AND SUPPLIES: Alkaline Cleaning, Pickling, Degreasing, Buffing, Polishing, Blasting, Plating Porcelain Enameling, Purifying, Painting Equipment and Supplies; Rust Preventives; Abrasives.

WELDING AND JOINING EQUIPMENT AND SUPPLIES: Gas, Resistance and Arc Welding Equipment and Supplies; Electrodes; Adhesives, Fasteners; Hard Surfacing, Brazing and Soldering Equipment and Supplies.

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES: Microscopes and Attachments; Analytical and Mechanical Equipment; Gages, Comparators, Hardness Testers, Nondestructive, Electronic and Other Scientific Inspection Equipment.

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES: Electric and Vacuum Melting Furnaces; Refractories; Ferro Alloys; Foundry Irons and Coke; Rare Earths; Alloying and Refining Agents; Annealing, Soaking and Sintering Furnaces; Rolling Equipment; Industrial Gases; Foundry Equipment and Supplies.

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS: Castings (Malleable, Gray Iron, Steel, Non-Ferrous), Forgings, Extrusions, Powder Metal Parts, Springs, Stampings, Tubings, Weldments, Wire.

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Metal Progress

March, 1960 Issue

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Stabilized two-stage flame, no additives

One of a series

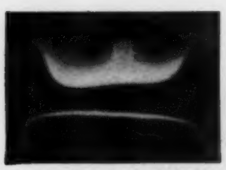
The burning question of cool flames

Between the brief stage of not burning and burning, many hydrocarbons react with oxygen at temperatures well below that of normal flame combustion. But the reactions are usually transient and hard to analyze. At the General Motors Research Laboratories, we have been able to investigate the *effect of chemical additives on cool preflames.*

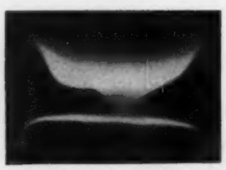
To do this, the almost invisible cool flames are stabilized for hours in a flat-flame burner, permitting careful examination of the retardation or acceleration effects of the additives. From more than twenty additives studied, experimental results indicate that some chemicals affect combustion through the mechanism of preflame reactions. We are now accumulating new information on these additives' mode of operation. For instance: emission spectra support the conclusion that tetraethyl lead reacts with the oxygenated compounds formed in cool flames to yield lead oxide vapor. These findings of when and how lead oxide is formed are important in resolving a current controversy of science — the combustion behavior of tetraethyl lead.

Studies such as this may lead to more economical and effective means of controlling unrestrained combustion — such as "knock" in reciprocating engines. The work is typical of GM Research's effort to provide useful information for a moving America. And in this way continue to keep our promise of "More and better things for more people."

General Motors Research Laboratories
Warren, Michigan



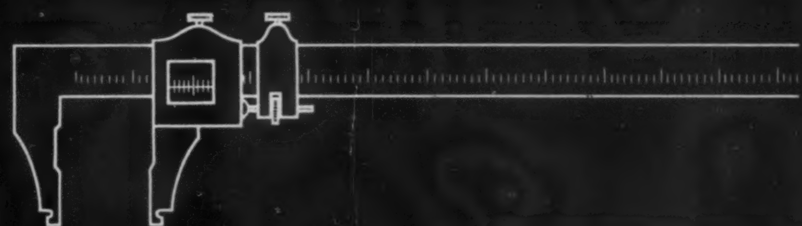
Iron carbonyl, an antiknock

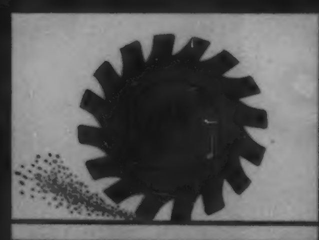


Ethyl nitrate, a proknock

Iron carbonyl retards, ethyl nitrate accelerates central portion of cool flames.

Circle 899 on Page 48-A





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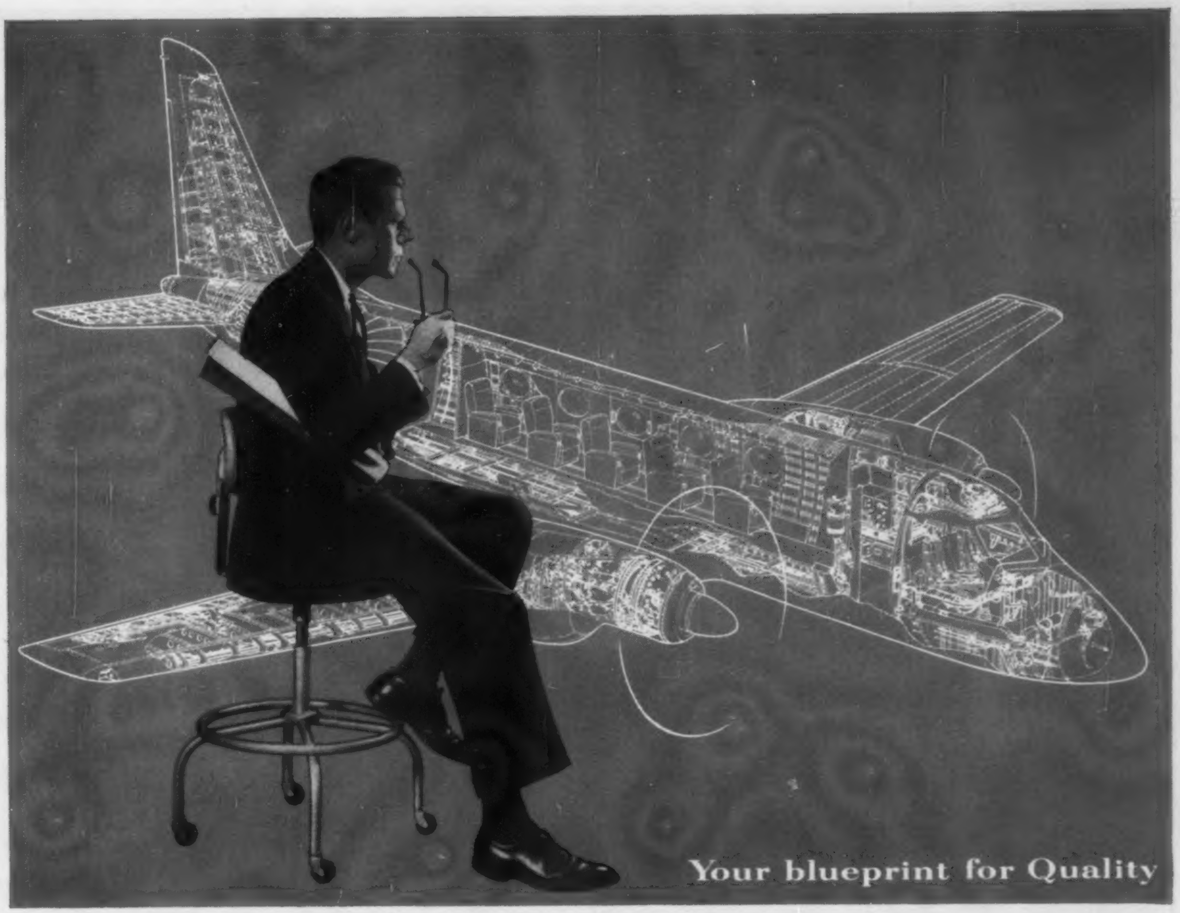


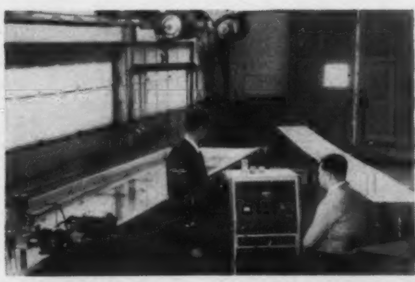
The Man is Sperry Ultrasonics

For years he has collaborated with Grumman's Quality Control Group and engineering personnel in developing ultrasonic test methods and techniques to assure the structural integrity of the material used in carrier-based aircraft.

These nondestructive flaw detection techniques, developed for structures required to withstand rigors of in-fleet service, are now applied to Grumman's new business airplane, the Gulfstream..... "built to withstand fatigue for the equivalent of more than fifty years of operation."

Sperry sales engineers are recognized authorities on the application of ultrasonic techniques in nondestructive testing. They are the link that sparks Sperry research and development teams to create the tools to meet your quality control requirements.

When there is a quality control problem, call the man who is Sperry Ultrasonics.



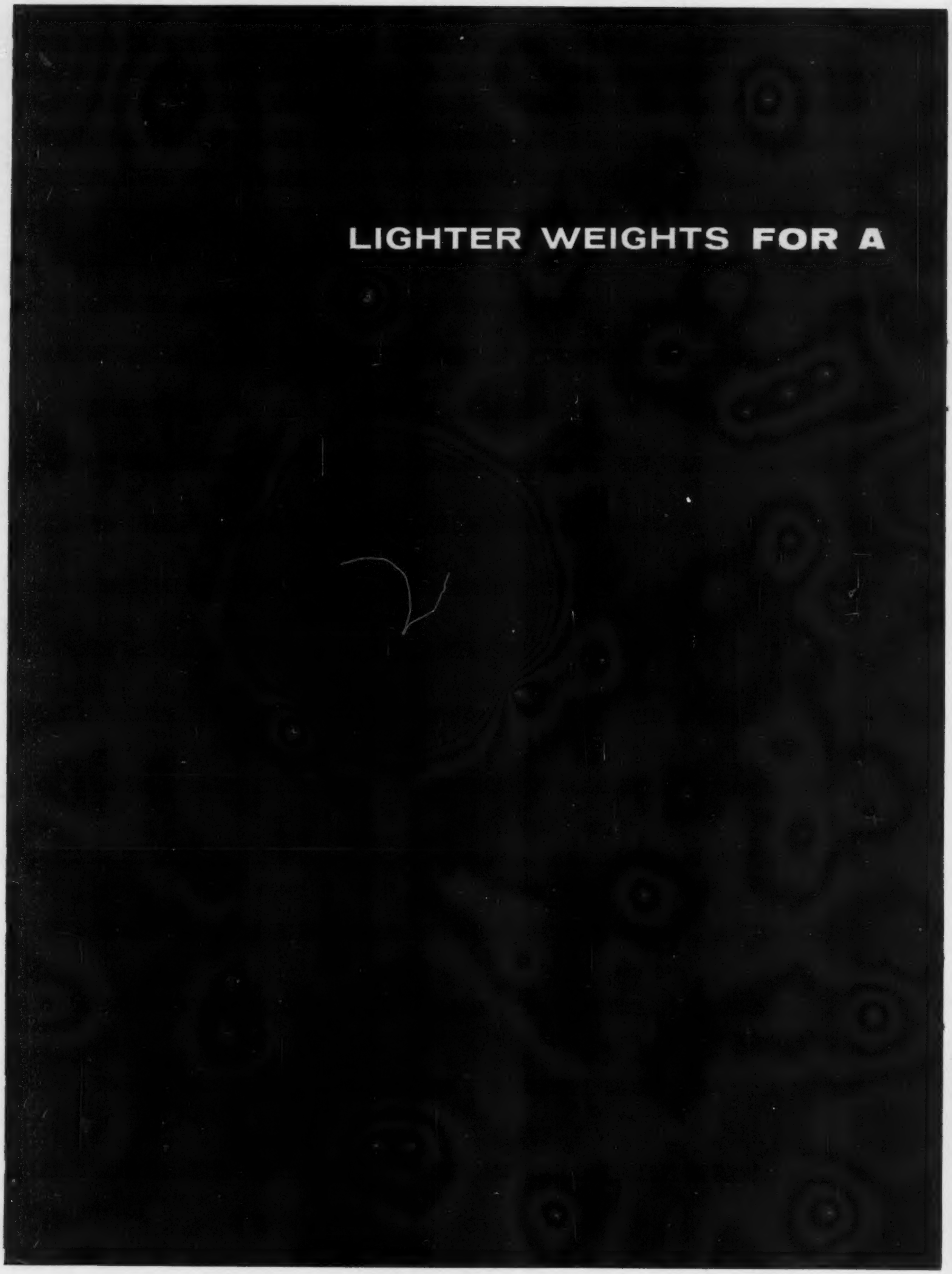
Quality Control Group inspects Gulfstream wingplank section in Grumman Sonic Laboratory.

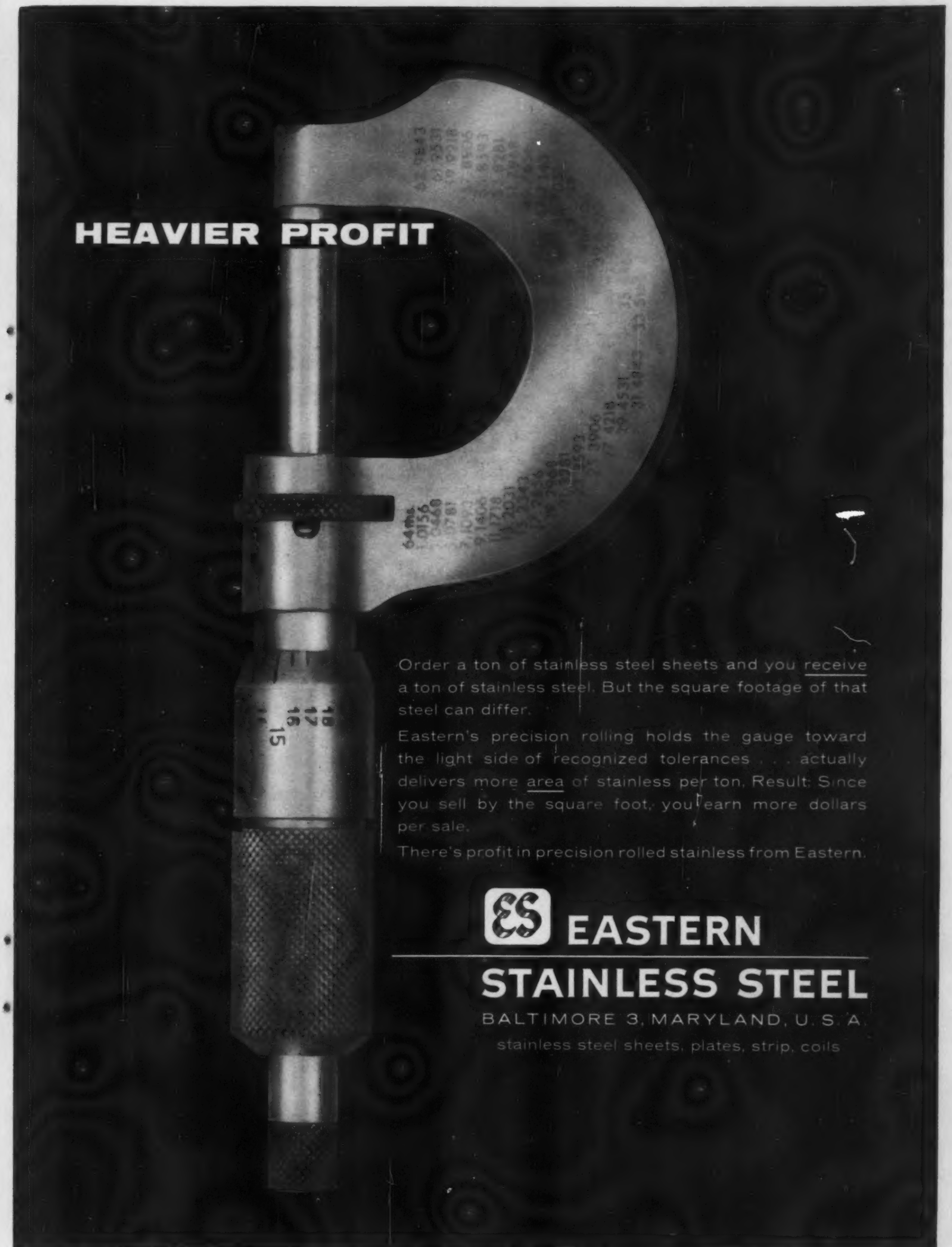
Sperry Products Company

DIVISION OF HOWE SOUND COMPANY

503 Shelter Rock Road, Danbury, Connecticut

Circle 962 on Page 48-A


LIGHTER WEIGHTS FOR A



Circle 903 on Page 48-A

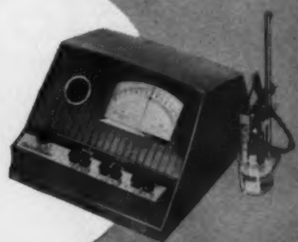
HARSHAW SCIENTIFIC

Spotlights pH Meters

With our comprehensive line of pH meters—ranging from the ultra-sensitive Beckman Model GS to the inexpensive Beckman Pocket Model—we offer the proper instrument for your particular need.

Representative models are described briefly below. We welcome your requests for more detailed information.

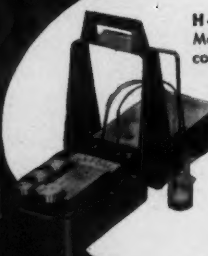
H-29604—Beckman Pocket pH meter, battery operated. 6″ x 3″ x 2″ deep. Light weight with unique combination glass and reference electrode which permits holding meter in one hand while taking readings, leaving the other hand free for recording . . **$99.50**



H-28915—Beckman Zeromatic pH meter, line operated. Simply push button and take pH or millivolt reading. Drift free, no warm-up time, line voltage compensation, continuous 0-14 pH scale. Outlets provided for recorder, polarizing current, etc. . . . **$295.00**

H-28901—Beckman Model GS pH meter, battery operated. For special pH problems and applications requiring extreme precision. This ultra-sensitive instrument is accurate to 0.0025 pH. The meter is a modified model G, which provides 20 times the sensitivity of standard null-meter measuring circuits. Utilizes same electrodes as model G. **$625.00**

H-28900—Beckman Model G pH meter, battery-operated. Designed for highest precision and versatility in pH studies, oxidation-reduction potential measurements and titrations with accuracy and reproducibility to ±0.02 pH. **$475.00**



H-29602 — Beckman Model N-2 pH meter. A compact, battery operated meter in carrying case designed especially for portability. Ideal for field use. Range 0-14 pH. Case has compartment for electrodes, beaker and solutions . **$360.00**

H-29601 — Beckman Model N-1 pH meter, battery operated. Range 0-14 pH. Temperature compensator covers 0-100°C. Rapid measurements to 0.1 pH and with careful technique to 0.03 pH. **$310.00**

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Circle 904 on Page 48-A

Circle 905 on Page 48-A

The Billings & Spencer Co. produces hundreds of quality forgings daily—from aircraft and missile parts to hand tools. Speedomax H temperature control helps hold rejects to a minimum.

Control of forge fires improves profitability...

... at The Billings and Spencer Co., Hartford, Conn., where Speedomax® H controllers are providing the right temperatures for a variety of forgings, ranging from mechanics' hand tools of carbon and low alloy steels, to aircraft and missile parts made of today's modern high temperature alloys. The combination of precise temperature control, good furnace design and good forge-shop practices has not only reduced rejects . . . it has saved fuel and greatly improved furnace life. Rugged, compact and completely reliable, Speedomax H is providing similar benefits for numerous other heat treat operations . . . is helping both to modernize production, and to produce a quality product. *Whatever your heat treat, it'll pay you to investigate Speedomax H!* For details, contact your nearest L&N office, or write 4927 Stenton Avenue, Philadelphia 44, Pennsylvania.

Unaffected by either high ambients or continuous vibration, Speedomax H provides dependable, uninterrupted regulation of forge temperatures.

LEEDS NORTHRUP
Instruments · Automatic Controls · Furnaces

Circle 906 on Page 48-A

Just add water...

for reliable, low-cost high temperature protection

With Norton ALUNDUM* Castables it's practically that simple and economical to make refractory shapes that would otherwise cost you far more. You make your own molds and, following a few simple directions, mix and pour your own furnace arches, domes, covers, spouts for melting furnaces, etc. Even the most complex shapes can be formed easily and inexpensively. And ALUNDUM Castables are ideal for furnace conditions in all types of atmospheres at temperatures up to 3,300°F.

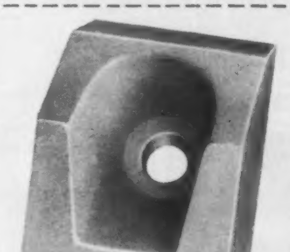
This versatile castable is available in two types:

1. ALUNDUM 33-I Castable, made up principally of pure fused aluminum oxide *bubbles*. Its light weight and high insulating properties suit it for use in furnace applications subject to high temperature radiation, but mild gas and flame erosion. It is often used as a back-up for ALUNDUM 33-HD material in linings and roof arches.
2. ALUNDUM 33-HD Castable, made up principally of dense, fused *grains* of pure aluminum oxide. It is ideally suited for forming dense, monolithic surfaces where conditions are more severe — provides positive protection against flame impingement and abrasion.

Cut down time for repairs, your inventory of required shapes . . . and save with Norton ALUNDUM Castables. Write for new catalog with complete characteristics and casting instructions. NORTON COMPANY, 322 New Bond Street, Worcester 6, Massachusetts.

*Trade-Mark Reg. U. S. Pat. Off. and foreign countries

Imagine the savings in making complex shapes like this tapping block right *in your plant.*



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Circle 907 on Page 48-A

Take advantage of Stokes

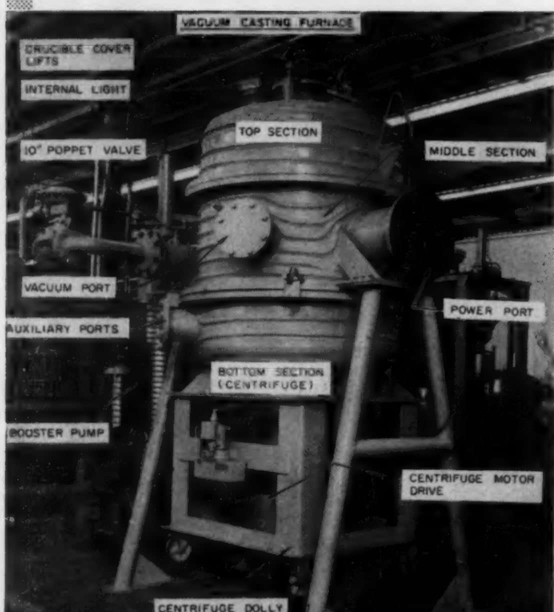
...and you profit from

From R&D to system installation and operation, Stokes unmatched technical competence and unparalleled experience assure you the most complete "package of progress" in the industry . . . with a pay-off in performance.

New vacuum methods and techniques—pioneered by Stokes—are finding more and more applications in the metallurgical field. These advances are leading industry out of old impasses . . . while reducing production costs.

Stokes equipment in the nuclear field, for example, has been used to develop new methods for plutonium melting and casting, uranium melting on a production basis, and radioactive materials handling. In another area, Stokes vacuum stream degassing equipment has already helped reduce hydrogen embrittlement in metals . . . is now pointing the way to better "killing" of steel. And still more developments are in the offing . . . in melting, refining, heat treating, sintering and brazing . . . and in Vacuum Metallizing of thin and heavy coatings for both functional and decorative applications.

Stokes experience in the manufacture of components, equipment and systems helps take the guesswork out of your operation. For instance, Stokes can supply a complete turnkey installation—erected, tested and delivered "in operation". Stokes stocks components for faster delivery to eliminate costly holdups. Standard



Radioactive materials handling investigations are safely carried out with this Stokes prototype vacuum furnace. It is remotely operated by manipulators and other external controls. This installation represents another specific requirement met through Stokes flexibility.

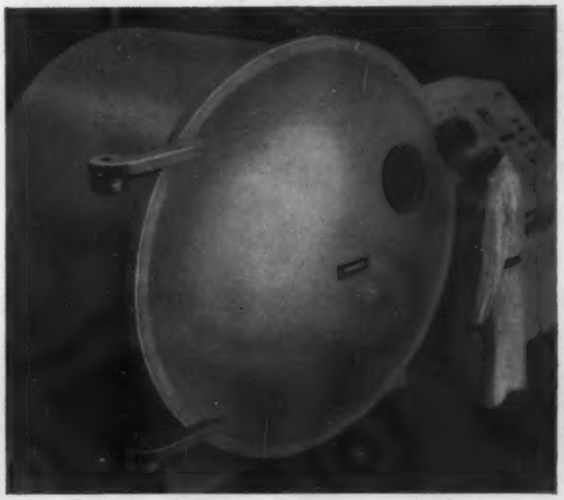
Uranium melting on a production basis is accomplished by this Stokes induction melting furnace. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of poured materials. It is typical of Stokes inherent flexibility.

Progress in Vacuum Metallurgy

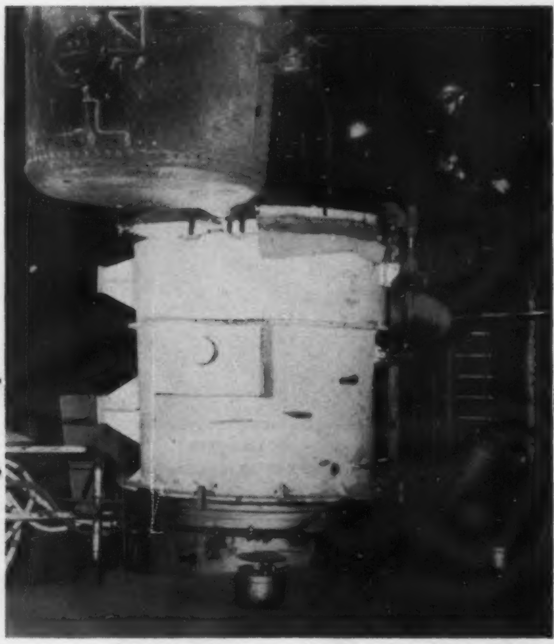
"Single Source" Service

vacuum equipment ranges from small compact R&D models to full production units. Stokes is geared to meet specific customer requirements for many types of special metallurgical equipment. All Stokes systems are offered complete, making Stokes a single source of responsibility for performance and reliability, both before and after the sale.

Let Stokes put its unparalleled experience and facilities to work for you. Stokes' Engineering Advisory Service will assist you in planning and designing an installation that will best serve your exact needs. While it's fresh in your mind, why not call Stokes . . . and get all the details.



Heavy coatings with new continuous sources—cadmium and aluminum—are now possible. Stokes manufactures a complete line of vacuum coaters . . . ranging from small R&D models to this new 72" production unit. Modifications of basic designs are easily made . . . extending applications and system size almost without limit.



First acid open hearth, vacuum stream ladle degassed—Air pouring of multiple ingots in the United States took place at Ohio Steel Foundry in May. Stokes provided the equipment. The results showed low hydrogen values, good inclusion reduction and excellent physical property improvement.

Vacuum Metallurgical Division
F. J. STOKES CORPORATION
5500 Tabor Road, Philadelphia 20, Pa.

STOKES

Circle 908 on Page 48-A

two more cases where **PARTS PRODUCED FROM**

provide excellent bearing properties

CASE HISTORY

MUELLER BRASS CO. 600 ALLOY screw machine product used in heavy duty farm equipment

This heavy duty planetary pinion shaft, made as a screw part from tough "600" series bearing alloy, was the answer to a continuing wear problem encountered in the driving mechanism of heavy-duty farm equipment and big trucks. The part is machine produced to exacting tolerances and all necessary finishing operations are done by Mueller Brass Co. so the pinion shaft is ready for installation when received. Since "600" alloy parts have been installed, no operating failures have been reported and the shafts have proved far superior to the material formerly used.

MUELLER BRASS CO. ANALYSIS SERVICE

You get sound, unbiased advice on the one best method of making your parts because Mueller Brass Co. is the only fabricator in the country offering all these methods of production. An experienced Methods Analysis Department has at its command a complete knowledge of the advantages and limitations of each production process. This unique technical service is your assurance of getting the best product at the best price . . . made the one best way!

COLD-PREST IMPACT EXTRUSIONS

PLASTIC INJECTION MOLDING

MUELLER BRASS CO.

MUELLER BRASS CO. 600 ALLOY

and maximum wear resistance in tough applications

CASE HISTORY

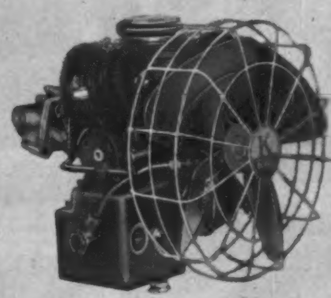
MUELLER BRASS CO. 600 ALLOY forgings used in aviation air compressors

Analyzing the job requirements of Walter Kidde & Company, Inc., for a main driving cam component to be installed in a reciprocating type of aircraft air compressor, Mueller Brass Co. Methods Analysis Engineers decided on a forging fabricated from "600" alloy as the most practical method of production. Since the cam forms the prime component of the driving mechanism, it must have good bearing wear surfaces and because the compressors are used in the aviation industry, the cams must be completely dependable. The close grained, strong forging that resists combination compressive and tensile stresses was the answer.

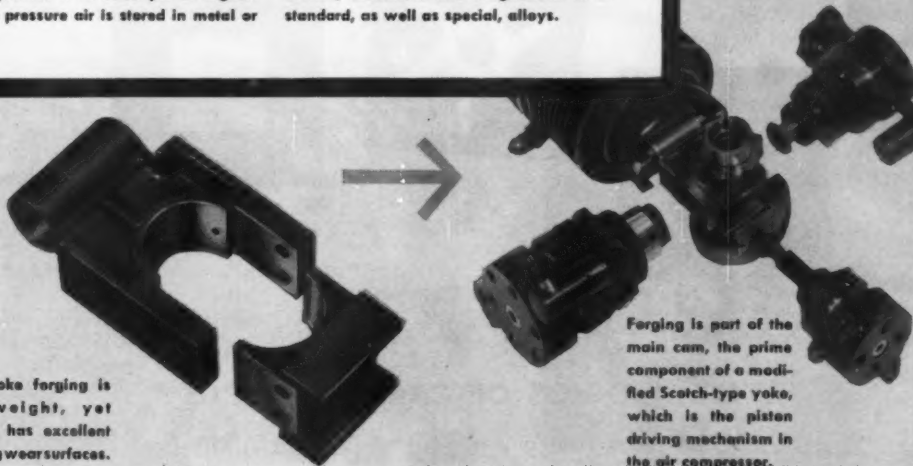
A typical compressor takes in ambient air and compresses it to 3000 psi or higher. This high pressure air is stored in metal or fiberglas containers until needed for actuation of pneumatic system components such as solenoid control valves, brake valves, manual control valves or actuators. These and other pneumatic units retract the entrance door, operate landing gear, wheel brakes, nose wheel steering systems, propeller brakes or perform other functions.

Aircraft in which Kidde compressors are installed include the Boeing 707, the Douglas DC-8, the Lockheed Electra, the Fairchild F-27 and various military aircraft.

Mueller Brass Co. produces press, hammer or cored forgings of any practical shape from a few ounces to 150 lbs. in brass, bronze, aluminum and magnesium in 27 standard, as well as special, alloys.



Aircraft air compressor equipped with hydraulic drive delivers air compressed to 3000 psi at the rate of 6 cfm.

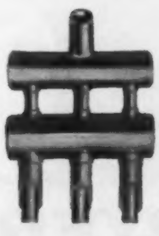


This yoke forging is lightweight, yet strong; has excellent bearing wear surfaces.

Forging is part of the main cam, the prime component of a modified Scotch-type yoke, which is the piston driving mechanism in the air compressor.

POWDERED METAL PARTS

SAND CASTINGS



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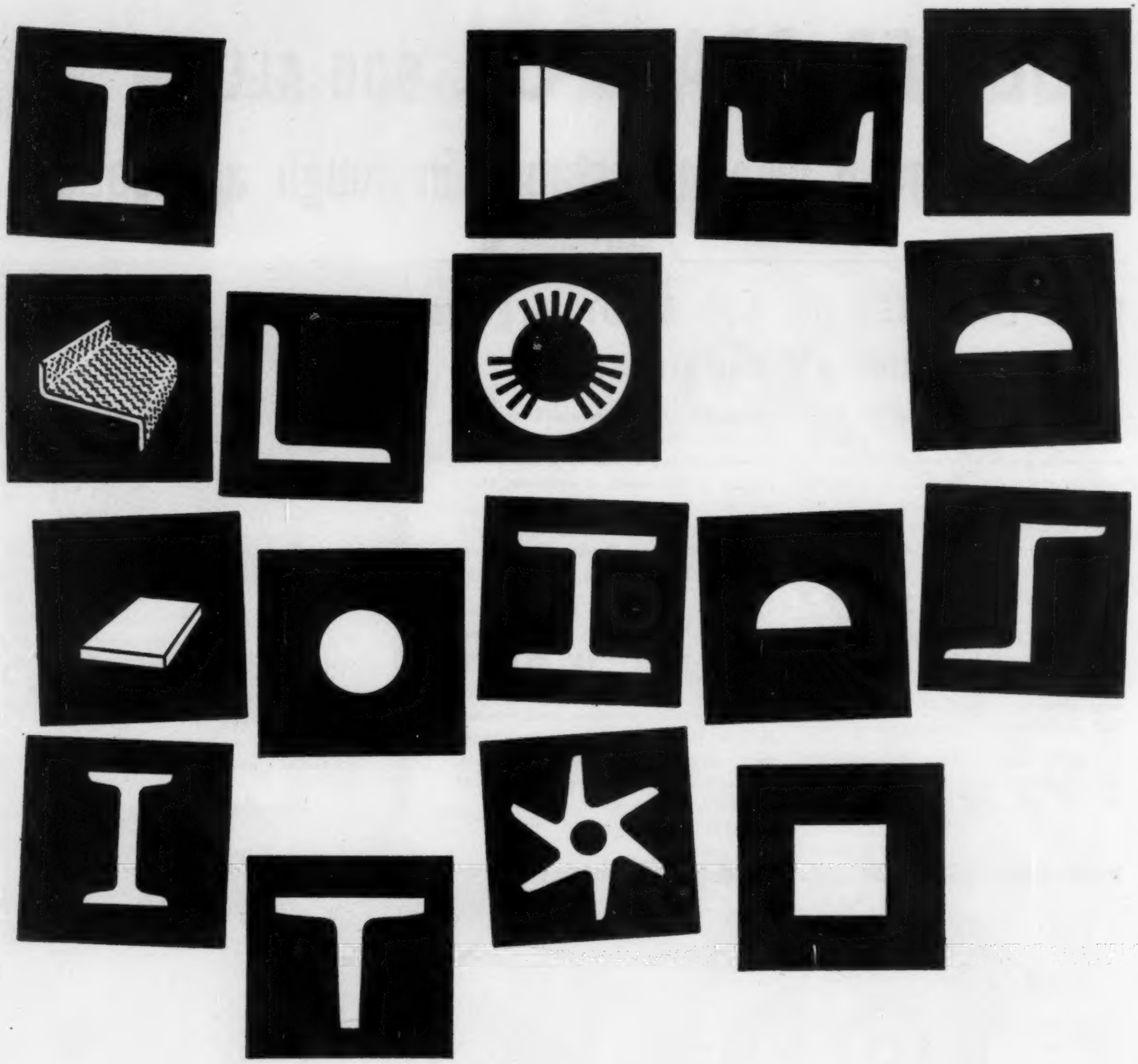


Circle 910 on Page 48-A

Metal Progress

Technical NEWS in Brief

New High-Strength Steel for Rocket Cases

The critical need for minimum weight in solid propellant rocket casings has led to the use of very high-strength materials – for example, steels with a yield strength over 200,000 psi. At these high strength levels, many metals act in a brittle manner when small flaws are present in the alloy or are generated during fabrication of these thin-walled pressure vessels. The result has been that service failures have occurred by brittle fracture at stresses which were well below the design stress level; this level is usually based on yield strength of the metal.

At the A.S.M. Golden Gate Metals Conference in San Francisco last month, G. K. Bhat reported on work conducted at Mellon Institute for Industrial Research to develop a new ultra-high-strength steel which could be readily fabricated into lightweight, large-diameter missile motor cases by every facility available in this country. Another objective was that these motor cases be heat treatable, consistently, to a uniaxial yield strength level (0.2% offset) of 225,000 psi.

According to Dr. Bhat: "Our preliminary approach in the development of this new steel was to get an insight into the nature of brittle failure and heterogeneity of the steel matrix heat treated to strength levels in the range of 220,000 to 240,000 psi." He illustrated this point at the conference by showing some basic differences between a lean alloy steel, typified by A.I.S.I. 4137, and a medium alloy steel of the H-11 type. A rather startling observation was made: Although the burst pressure of H-11 steel chambers was high, the biaxial yield strength was significantly lower as the strength level increased. At the 240,000-psi. level, the H-11 chambers failed prematurely – the vessel shattered into several pieces.

From these studies the Mellon researchers formulated two basic principles to be followed in their alloy development work:

- The chances of obtaining very high biaxial

New Steel for Rocket Motor Cases
Vessels of 4137-Co Are
Fabricated for Pressure Tests

strength are greater in a low-alloy (lean composition) steel than in an over-alloyed steel.

- The composition must be properly balanced so that the steel matrix when heat treated to a high strength level (over 220,000 psi.) and stressed, will distribute the stresses evenly.

Said Dr. Bhat: "With these ideas in mind, we pioneered a modified 4137 cobalt steel." Nominal composition of the new steel, called MX-2 at Mellon, is 0.39% C, 0.70% Mn, 1.00% Si, 0.010% P, 0.010% S, 1.10% Cr, 0.25% Mo, 0.15% V, 1.00% Co. In discussing effects of alloying elements Dr. Bhat pointed out that, within limits, the strength of a steel increases proportionately with increase in carbon content. To get a minimum yield strength of 220,000 psi., steel must have a carbon content of about 0.4%. Carbon content over this impairs ductility, toughness, and weldability of steels unless excess carbon is tied up as carbides by carbide-forming and other structure-stabilizing elements.

Another way of getting high yield strength is through addition of silicon and elements which have an effect similar to silicon. Silicon retards the tempering reaction and the formation of cementite, which in early stages of tempering, causes a type of brittleness. It was also noticed that cobalt retards tempering and strengthens ferrite in a manner similar to nickel without, however, conferring strain-aging characteristics.

The cobalt-modified A.I.S.I. 4137 steel is useful in missile and other airframe applications which require a minimum 0.2% yield strength of 225,000 to 235,000 psi. Fabrication of the steel has not indicated any problem areas; it welds, deep draws and forms readily. The new steel is being produced commercially by Universal-Cyclops Steel Corp. Both U.S. Steel Corp. (up to 22-ton heats) and Latrobe Steel Co. have made it in experimental quantities. The program at Mellon Institute, with which Dr. Bhat is associated, is directed by Harry L. Anthony. More information on properties of this new steel and future possibilities will be given in an early issue of *Metal Progress*.

A Better Way to Weld High-Strength Steel

Premature failure of rocket motor cases because of poor welds was one of the earliest problems which confronted missile manufacturers. A possible solution, but not always practical, is to eliminate welds from the structure by redesign. Size of the cases often prohibits this. The alternative is to learn how to make better welds.

This was the problem tackled by the Redstone Div. of Thiokol Chemical Corp. at Huntsville, Ala. Work at Thiokol and Armour Research Foundation (reported by T. H. Burns, chief of Thiokol's metallurgy and manufacturing techniques section, at Armour's sixth annual Midwest Welding Conference) indicates that ultra-high-strength steel can be welded by a technique which calls for the use of filler wire of the same composition as the parent metal except for lower carbon content and cold work of the weldment.

A typical fabrication technique is to hydrospin two cylindrical sections of the motor case from ultra-high-strength steel (300 M or Tricent, vacuum melted) then join the two sections by girth welding, thus forming the full-size case. When filler wire of the same composition as the parent metal was used the welds were strong but lacked ductility. Next step was to use filler wire of lower carbon content (0.25 to 0.29% C) than the parent metal (0.40 to 0.45% C for Tricent). Ductility was improved to about 10 to 15%, up from about 1% or less in welds of normal carbon, but strength was decreased. Final answer was to cold work decarburized welds by spin forging. Grain structure then becomes quite similar to that of the parent metal. In this condition – decarburized and cold worked – the welds average about 300,000 psi. tensile strength, 245,000 psi. yield strength and 7½% elongation.

After being welded, cases are heat treated at 1700 to 1900° F., air cooled, then tempered at 600° F. There are some who advocate tempering at 1000° F. Better burst test results are claimed. Some decarburization of the surface through use of controlled furnace atmospheres is desired since it decreases notch sensitivity of the metal at high strength levels. A depth of about 0.015 in. is recommended.

Foils Welded by Ultrasonics

One of the major advantages of ultrasonic welding is that it joins metals without heat, a useful characteristic when foils must be welded. Consider the ultrasonic welder recently introduced by Vibro-Ceramics Div. of Gulton Industries, Inc., Metuchen, N. J. Designed specifically for welding thin metal (foil as thin as 0.00025 in. and up to 0.006 in. can be welded), the machine uses a rotating tip (picture). Operating costs are claimed to be low because power requirements are moderate and the ceramic transducer provides a high ratio of power output to power input. The equipment

ROTARY ULTRASONIC WELDER
It Joins Flat or Semicircular Foil

also maintains a preset welding angle, speed, and pressure, thus reducing the chance for human error.

Lowering Sulphur in Molten Steel for Castings

Engineers at the General Electric Research Laboratory have devised a new method for reducing sulphur in steel used for steel castings. According to A. J. Kiesler, who discussed this subject at the Electric Furnace Conference (A.I.M.E.) in Cleveland recently, sulphur can be lowered to less than 0.005% without undue difficulty.

This novel system was developed to take advantage of the chemical characteristics of molten sulphides. Activities of iron and calcium sulphides vary with melt analysis. When carbon and silicon are high, sulphur has a greater tendency to leave the bath than when those elements are low. Thus, it is best to remove the sulphur before oxidizing the other impurities.

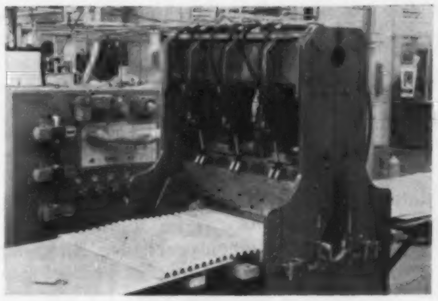
Here is the procedure: First, the charge is melted down with the conventional fluxes – ore and lime. As soon as the ferrous oxide (FeO) and phosphorus contents have been lowered to the proper levels, the slag is removed. Next a second slag (which has been premixed) is added. Consisting of two parts of lime, one part of graphite, and one part of finely divided silicon, this slag is carefully worked into the heat by vigorous mixing. (At this point, 0.10 to 0.15% of aluminum pig can also be added to help reduce the sulphur).

When the sulphur has reached the desired low point, the slag is removed. Otherwise, sulphur may revert from the slag to the melt. As a final step, the melt is blown with oxygen to oxidize carbon, manganese, silicon and aluminum. During this operation, the metal is protected from sulphur-bearing materials to maintain the sulphur content at the minimum previously established. Conventional tapping and pouring complete the process.

Corrugation Forming to Close Tolerances

A machine that forms corrugated sections to extremely close tolerances from superalloy sheet metals has been developed by manufacturing engineers at Boeing Airplane Co.'s Aero-Space Div. These corrugated sheets can be spot welded in place between two smooth sheets of superalloy to form a sandwich panel. Such panels are strong, relatively light and may be used in wing or fuselage skins for ultra-high-speed aircraft.

The machine consists of two tables, with punch and pressure bar between (photo). A sheet of superalloy is clamped between the punch and pressure bar, with tables extended. The punch and pressure bar move in unison in a downward direction and the two tables move toward each other, stopping when the desired angle of bend is obtained. By confining metal elongation to the bend areas and by using only enough elongation to set the formed corrugation, uniform bends with a minimum thin-out of metal are produced.



MACHINE FOR CLOSE-TOLERANCE CORRUGATIONS
Height of Corrugations in
René 41 Hold ±0.003 In.

Height tolerances of finished corrugations can be maintained at ±0.003 in. Different requirements in corrugation size, shape and material thickness can be handled by changing relatively inexpensive, removable die inserts. Minor changes in size and shape require only a simple adjustment of mechanical stops.

Information Searching Service Expanded

The American Society for Metals Documentation Service, first announced in January 1960, is now expanding its coverage of the important world's literature. This new automated service, which provides fast, prompt and up-to-date information on problems of current interest to metallurgists and the metal industry, will henceforth be able to draw on an ever-increasing fund of knowledge.

Until now the material being fed into the machine searching "library" has been the world's literature on metallurgy as provided by the abstracts published in the A.S.M. *Review of Metal Literature*. By a cooperative arrangement between the National Science Foundation, Western Reserve University and the A.S.M., additional material will be fed into the system in fields of peripheral interest to metallurgists – inorganic chemistry, solid-state physics, mechanical engineering, business information. Thus, the number of documents abstracted for searching will be increased more than three-fold – from the 12,000 abstracts published annually in the *Review of Metal Literature* to about 40,000 abstracts annually.

Also, by virtue of the Grant, patents, government reports, dissertations and trade literature (not included in the *Review of Metal Literature*) will be abstracted and encoded for machine searching. Thus, a subscriber to the searching service will be assured that all possible sources will be combed for the answer to his vital information problems.

For further details and information on subscrip-

tion costs, write to Documentation Service, American Society for Metals, Metals Park, Novelty, Ohio.

Materials Progress in Ceramic Honeycomb

Materials engineers are looking to ceramics and ceramic-metal combinations for solutions to some of tomorrow's most difficult problems. An example of progess being made can be seen at Boeing Airplane Co. where a technique has been developed for manufacturing ceramic honeycomb structures. They are light and strong and will withstand temperatures of 3000° F. or more. Boeing's work is under direction of W. M. Sterry, ceramics group supervisor in the company's Aero-Space Div.

The technique, which employs thin skins and thin corrugations of heat resistant ceramic oxides, permits fabrication of ceramic structures similar to metal honeycomb sandwiches. Panels for nose cones and radomes, which employ compound curves, can be formed of ceramic honeycomb on a production basis.

Ceramic oxides, such as alumina, zirconium oxide, or fused silica, are finely ground and combined with suitable binders to form a paste. This material is rolled under heat into thin, dense sheets which are flexible enough to allow sharp bends. The core is shaped by corrugated rolls. The ceramic honeycomb assembly is fired in a furnace to give a strong self-bonded unit.

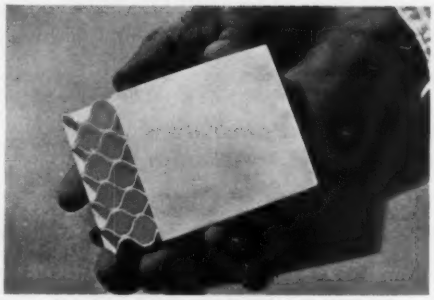
The ceramic sandwich has advantages in designing electronic structures such as radomes. Compared with solid ceramic radomes, they allow the use of a broader band of frequencies. As a result, it may be possible to achieve efficient transmission of power from several different antennas within a single radome.

Various types of honeycomb structures have been developed which may find application in heat resistant leading edges, nose cones and skins for hypersonic vehicles. One type is made from ceramic fibers, similar in appearance to wood pulp. Although these structures have lower heat resistance they stand up well to thermal shock. Insulating properties of these panels can be enhanced by filling the cells with low-density insulating material.

To develop ceramic materials with low curing temperature, phosphate-bonded aluminum oxide is being studied. Here, curing temperature is only 700° F. Chromium oxide can be added for more strength. To improve resistance to impact and thermal shock, molybdenum wires or screens can be embedded in the ceramic mixture.

Honeycomb panels also may be made of metal skins brazed to a ceramic core which has been flame sprayed with metal. However, the coefficient of thermal expansion of the metal and the ceramic core must be matched so the bond won't pull apart with changing temperature.

Today, honeycomb panels can be made from aluminum oxide which will withstand 2500° F. Zirconium oxide can be used and resistance goes up to 3500° F. Work is being done with oxides



Ceramic Honeycomb Panel
It's Light and Resists Heat of High-Speed Flight

and carbides of hafnium and thorium which will withstand 4000 to 5000° F., or even higher temperatures. Ceramic materials are under study which have extremely low (even zero) coefficients of thermal expansion. Other developments are in the area of laminated structures made by flame spraying alternate layers of ceramic and molybdenum.

From Here and There

A porcelain enamel finish has been developed for magnesium alloys. Possible applications include signs, building panels, cooking ware and home appliances. According to Dow Chemical Co., the porcelain can be applied to magnesium-thorium, magnesium-rare earth metal alloys and those of low aluminum content.

• • •

If there is any feeling that zirconium and its high alloys are little more than laboratory curiosities or scientific playthings, it should be corrected by the news that a committee of the American Society for Testing Materials voted in February on five specifications: (*a*) zirconium sponge, (*b*) ingot metals, (*c*) zirconium and alloy seamless and welded tubing, (*d*) hot rolled and cold finished bars, rod and wire and (*e*) sheet, strip and plate.

In this connection, perhaps it should be noted that next month's issue of *Metal Progress* will feature an expanded Data Sheet on properties of Zircaloy-2.

Can You Do More With Flame Hardening?

For the answer to this question, see the special report in *Metal Progress* next month. Details about setups used in hardening gear teeth, machine ways and rolls, as well as cost data and information on gases employed in the process will be given.

Producing for the Supersonic Age

Flight in the Thermosphere

I—Material Requirements for Thermal Protection Systems

By WILLIAM S. PELLINI
and WILLIAM J. HARRIS, JR.*

The severity of new environments is requiring new concepts which base the selection of airframe materials on thermal as well as on mechanical properties. (P11, P12, T24)

IT IS INTERESTING TO VISUALIZE a chart representing the increase in temperature requirements of airframe structures over the past 15 years. It would show a gradual increase from ambient temperatures to 500 to 600° F. during the late forties and early fifties, and then an almost vertical rise to temperatures exceeding the melting points of many materials during the middle and late fifties. The early and gradual increase in temperature requirements was due to the development of efficient jet engines for mach 2 to mach 3 cruise flight. The later and nearly vertical rise results from the development of rocket propulsion motors which enable glide and drag re-entry flight with nearly orbital velocities.

Up-to-Date Knowledge Needed

The severity of the new environment has required novel concepts which base the selection of airframe materials on thermal as well as on mechanical properties. Airframe components designed on this basis are defined as "thermal protection systems". Materials to provide optimum combinations of structural and thermal properties have posed particularly difficult problems in terms of order of priority and scale of effort. The difficulty stems, in part, from the fact that thermal protection design is unfortunately foreign to most engineers and designers who have been oriented almost exclusively by requirements based on mechanical properties.

The lead time for developing any new material for high-temperature airframes is of considerable concern to those acquainted with the intensive efforts to build airframes of titanium and steel. While these efforts were started during the late forties, we have yet to realize

*Mr. Pellini is superintendent, Metallurgy Div., U. S. Naval Research Laboratory, Washington, D. C., and Mr. Harris is executive director, Materials Advisory Board, National Academy of Sciences, Washington. Subsequent articles in this series will cover materials for heat sink systems (April); ablation, sublimation and transpiration systems (May); and radiative systems (June).

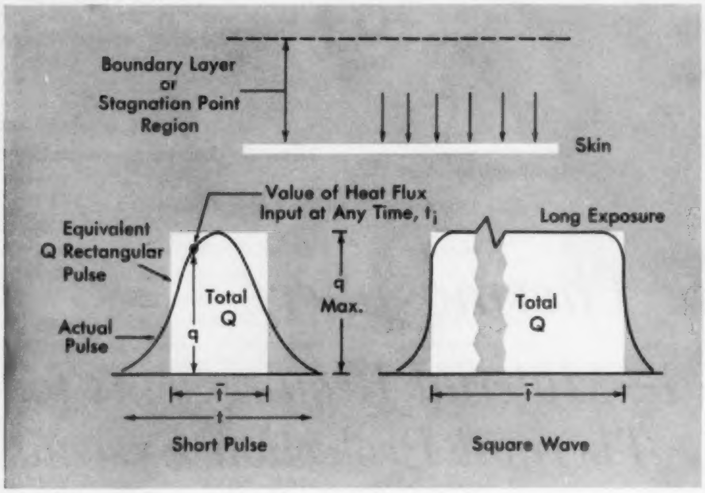


Fig. 1 — Aerodynamic Heating May Involve a Short Exposure as Illustrated by the Bell-Shaped Heating Pulse, or a Long One as Indicated by the Square Wave. Diagrams above provide an explanation of terms used: q is aerodynamic heat flux input to surface in Btu per sq.ft. per sec.; q-max is peak value of flux; Q is total input in Btu per sq.ft.

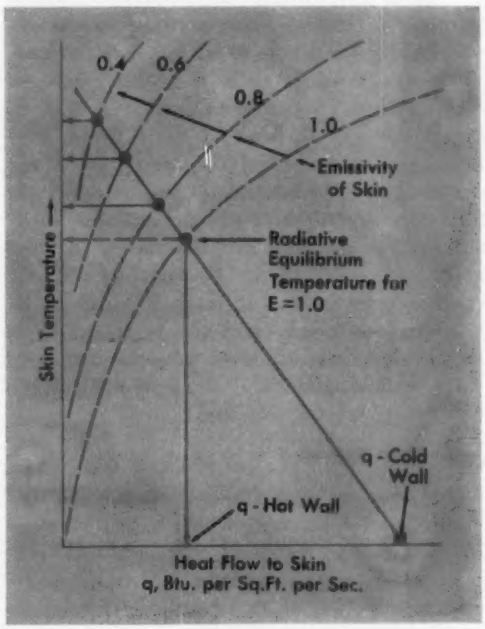
their full potentials in flight. It is entirely realistic to use this experience to estimate the great effort required to develop refractory metals and ceramic materials for various types of thermal protection systems.

While this series of four articles is restricted to materials requirements of airframe structures for thermospheric flight, it should be emphasized that this is but one of the many things that require urgent attention. The complexity of problems in materials evolves not so much from the need for high performance in terms of a specific property but of requirements for exacting combinations of properties. These desired combinations often include such "opposites" as high strength or high ductility coupled with low density; high resistance to temperature coupled with high resistance to shock and and to oxidation.

Unless some definite sense of direction is evolved to guide the investigator and unless the designer has a better concept of the order of magnitude or importance of the materials effort required, we shall continue to stumble along from one crash program to another. It is essential that management as well as the engineering and scientific staff be appraised of the requirements and the limitations. Unfortunately, venerable experience in either the materials or the design field is no substitute for up-to-date knowledge in this area of entirely new environmental problems.

The authors have been engaged in studies of present and future materials requirements, including those specifically related to the problems of thermal protection systems. This article and those which will appear in three subsequent issues of *Metal Progress* will summarize the general aspects of the thermal environment associated with high-speed flight, and discuss the extent to which capabilities of

Fig. 2 — The Radiative Equilibrium Temperature Attained by the Skin Is Shown to Depend on the Balance Between Radiation and Aerodynamic Heat Input. Note that radiation is a function of the surface emissivity



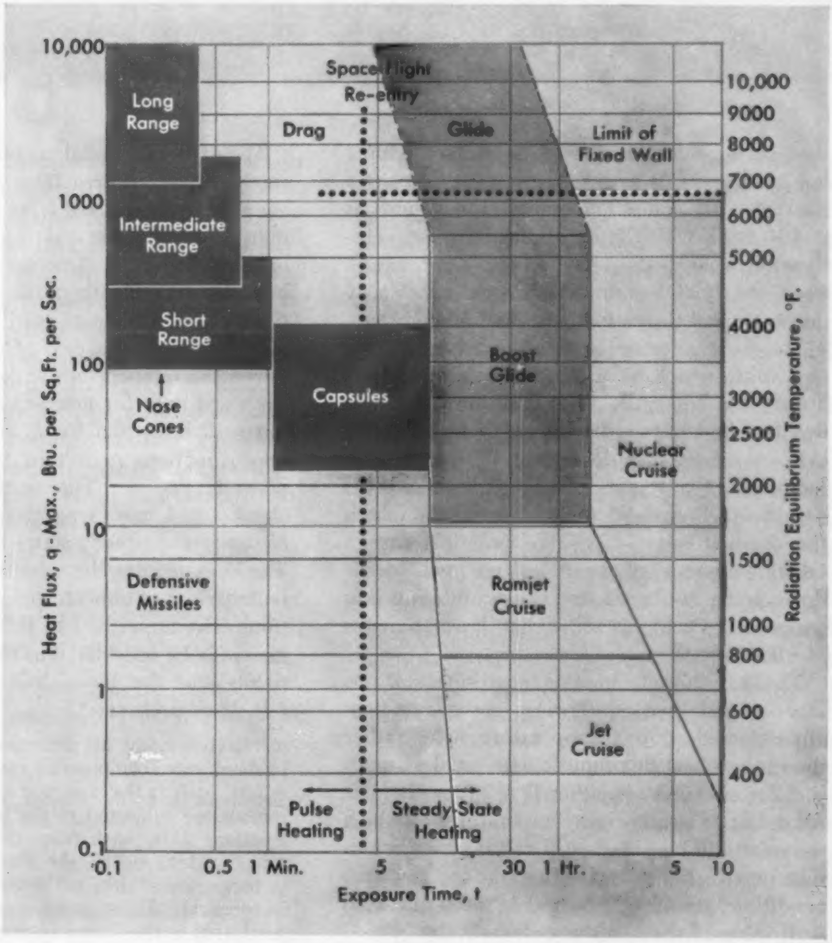
present or projected materials may be expected to meet the requirements.

Definition of Terms

To establish the significance of various terms which define the thermal environment, refer to Fig. 1. This represents the aerodynamic heat input to the structure as q, a heat flux at any given instant ordinarily expressed in terms of Btu.'s per sq.ft. per sec. Aerodynamic heating may involve a short-time exposure, as illustrated by the bell-shaped heating pulse, or a long one, as indicated by the square wave. The significance of the peak value, q-max., and the total heat input, Q, is evident from the illustration. The exposure time t, for pulse heating represents the width of a square wave having approximately the area of the bell-shaped pulse.

The equilibrium reached between radiation and aerodynamic heat input is illustrated schematically in Fig. 2. The temperature of the skin is usually supposed to be that of a perfectly insulated wall; that is, a skin backed by insulation which cuts the heat loss inwardly through the wall to zero. The temperature attained by the skin then depends on the aerodynamic heat input and the emissivity of the skin. The lowest skin temperature is attained by a surface having emissivity of a black body (E = 1.0). Figure 2 illustrates the

Fig. 3 – The Environmental Conditions of Various Classes of Vehicles Under Conditions of Steady-State Heating (Right) and Pulse Heating (Left). The lines defining the vehicle zones are not rigid boundaries but indicate generally expected locations



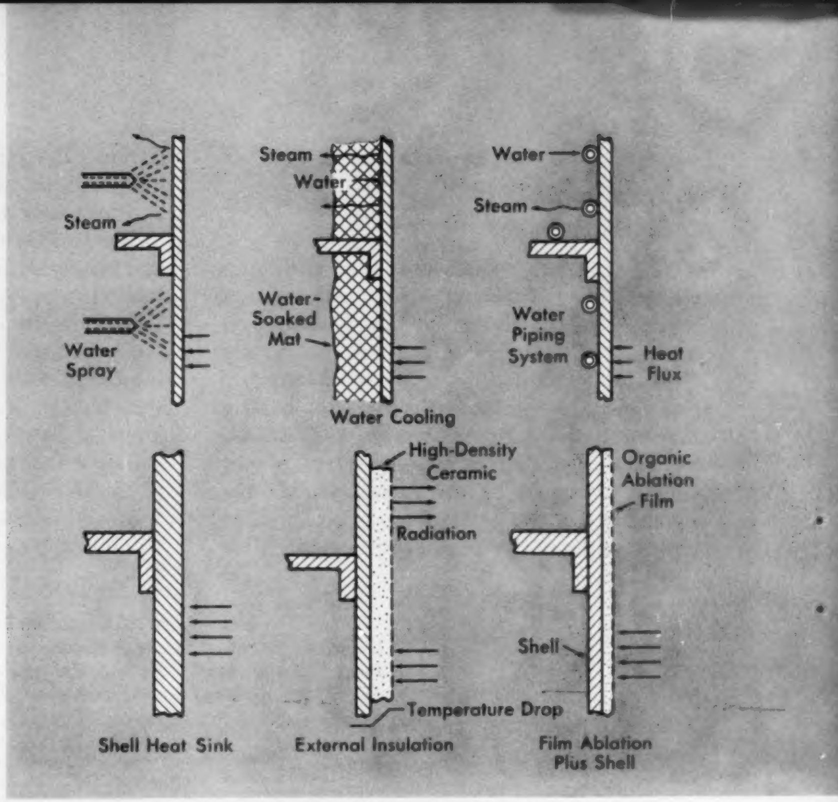


Fig. 4 (Left) – Systems for Augmenting the Heat Sink Capacity of the Structural Shell. Fig. 5 (Center, Page 73) – Absorptive Systems of Intermediate and High Heat Flux Capacity. These are based on the thermal capacity of the wall which does not melt, and by ablation or transpiration systems, which feature mass transfer. Fig. 6 (Right) – Radiative Thermal Protection Systems Required for Long-Time Exposure to Steady-State Heating

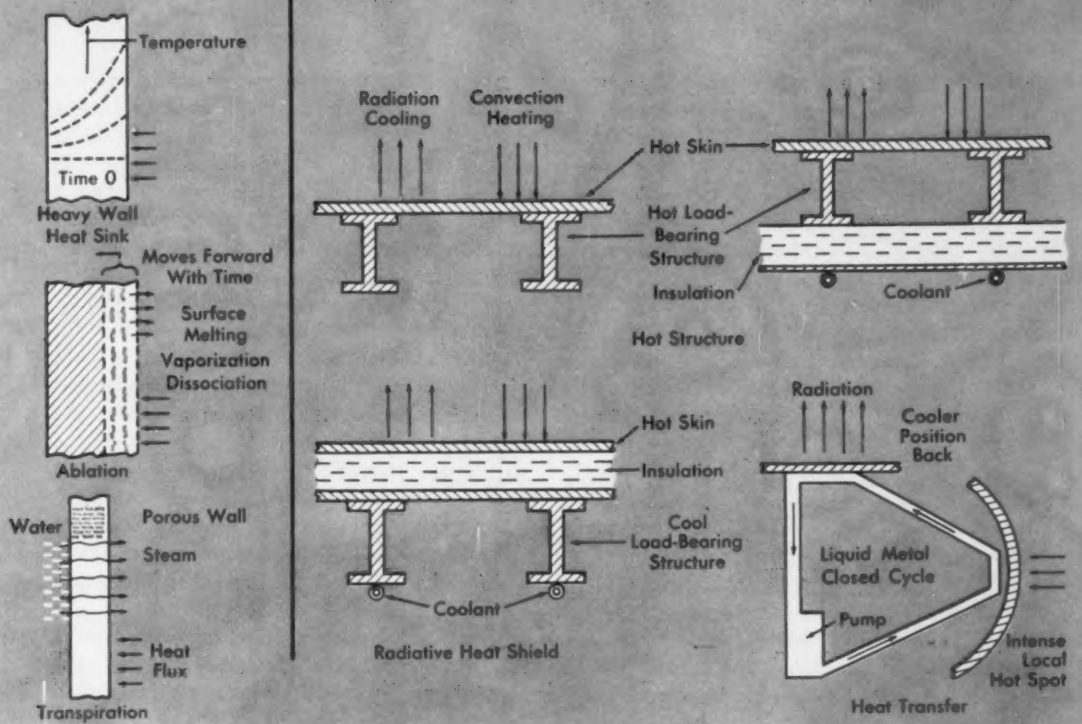
case of a cold skin surface in contact with a hot gas layer. At zero time the heat flux has a characteristic value, noted on the figure as q-cold wall, which is determined by the aerodynamic conditions. As the skin temperature rises, the heat flux to the surface necessarily decreases and the emission (radiation) increases.

The surface temperature ultimately stabilizes at a value which balances the convective heat flux to the hot wall, q-hot wall, and the heat flux radiated outwardly by the hot skin. For skin emissivities of less than unity the skin temperature automatically increases, so as to provide the required emittance flux to match the thermal input. For the practical case a certain amount of heat leakage will occur through the insulation, and the equilibrium skin temperature will be somewhat lower than as idealized.

The aerothermic heating conditions of surfaces at radiative equilibrium are conventionally referred to the temperature level rather than to the heat flux input. The usual assumption for emissivity is either E = 1.0 or E = 0.9. All radiative equilibrium temperatures to which we refer will be based on E = 1.0 unless otherwise noted. For pulse heating, the aerodynamic conditions are usually related to the q max-cold wall value of the aerodynamic heat flux.

The environmental conditions of various classes of vehicles reaching steady-state heating have been generalized from data quoted in the literature and from charts developed for preliminary designs. The various classes of vehicles involved with pulse heating were compared on the basis of cold wall q-max values (from similar sources). Cross references between the temperature scale and the flux scale are valid only for flux values considered on a hot wall basis and for E close to 1.0. These approximations permit us to prepare the diagram in Fig. 3. The vertical dotted line at about t = 4 min. separates (generally) pulse heating and steady-state heating conditions. The lines defining the vehicle zones are not rigid boundaries but indicate generally expected locations. The upper half of the various zones may generally be considered as relating to stagnation points and the lower half as relating to the 1-ft. back positions.*

*High-velocity air flow over a surface results in shock wave compression (stagnation) at forward points, such as the nose and leading edges. These regions are subjected to the highest heating rates. Positions 1 ft. back from the forward point are referenced to define the extent of the heat flux or temperature "drop off" from the maximum point. In general, the stagnation points are nonstructural, that is, they serve to support structural loads.



The chart also broadly separates vehicles by the nature of their flight. Drag re-entry vehicles are grouped in the upper left corner. Thrust flight vehicles, noted on the figure as "Defensive Missiles", are grouped in the lower left-hand corner. Lift flight vehicles, including the cruise and glide subdivisions, are grouped in the right side of the chart. The aerodynamic heat flux inputs for the lift flight systems, represented on the figure by "Space Re-entry Glide", may exceed the melting points of any known material. This limit is noted by the horizontal dotted line marked "Limit of Fixed Wall". The heat input limits for the drag re-entry class of vehicles might extend to over 10,000 Btu. per sq.ft. per sec.

Environmental Capabilities of Thermal Protection Systems

Thermal protection systems for flight vehicles may be divided into two general categories, based on the mechanism for handling the aerodynamic heat input:

1. Absorptive systems, which store most of the heat acquired.

2. Radiative systems, which dissipate most of it directly to the atmosphere.

Absorptive systems can absorb extremely high aerodynamic heat inputs because they may be designed to dissipate it without bringing much of the interior structure to a high temperature, even though the incident flux is dissipated, in part, by melting or vaporizing the surface. Because of the limited heat capacity of solids, absorptive systems are generally limited by weight considerations to short-time use — that is to say, to environmental conditions involving pulse heating.

Figures 4 and 5 show specific types of absorptive thermal protection systems. Figure 4 shows means for augmenting the heat sink capacity of the structural shell. Such systems may be expected to raise the flux limit or prolong the allowable time of exposure and include water cooling in various forms, sacrificial or ablating organic films, and transient-type external insulation (transulation). Figure 5 illustrates absorptive systems of intermediate heat flux capacity. These include heavy-wall heat sinks, which are based on the thermal capacity of the wall which does not melt, and ablation or transpiration systems, which feature mass transfer. The latter may also be considered as capable of resisting high heat flux. (Sublimation devices, which are most appealing for use at very high flux levels, may be included in the general class of ablative systems in this respect.)

Radiative systems may be used for pulse heat-

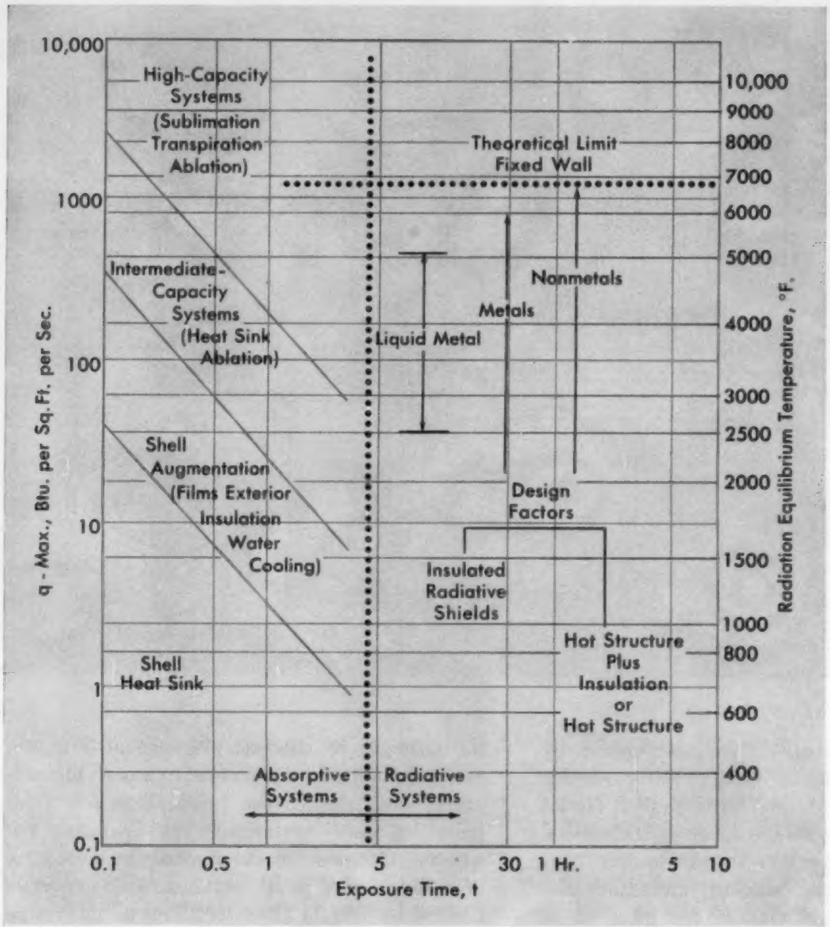


Fig. 7 – Applicability of the Various Types of Thermal Protection Systems. The delineation is not a rigid one but is intended to represent the most likely areas of use for each system

ing conditions only if the q-max value does not result in exceeding the melting point of the material. However, the principal need for such systems is for conditions involving long-time exposure to steady-state heating. Figure 6 illustrates various types.

The effectiveness of such systems as sketched in Fig. 4 to 6 depends on the emissivity of the surface, which determines the actual temperature attained by the structure and therefore affects the problem of materials selection. The hot structure system of Fig. 6 represents designs wherein the load-bearing structure operates at the skin temperature and fulfills the basic definition of a thermal protection system because it functions as a heat radiator where efficiency is related to the emissivity of the skin. A system which utilizes insulation placed in back of the load-supporting structure for keeping down the internal temperature is likewise defined as a "hot structure," or more specifically, "hot structure plus insulation". The insulated "radiative heat shield" of Fig. 6 differs from the hot structure in that the outer surface or radiative shield is not required to support structural loads and the structural members operate in a cooler environment.

Efficiency of Radiative Systems

Insulated radiation systems in time will develop a steady-state heat leakage to the interior when the insulation is saturated to heat capacity. For these conditions a heat absorption subsystem, such as the tubes containing

coolant shown in two of the sketches in Fig. 6, must be added if a fixed internal temperature is to be maintained. Accordingly, a weight penalty which increases with exposure time is a feature in such circumstances. The efficiency of radiative systems for long exposures may be considered in light of the fact that for an empty "hot wing" condition (no internal payload requiring insulation) the radiation from the skin is 100% of the aerodynamic heat input when equilibrium is attained. For such a condition there is no thermal protection weight penalty chargeable to the exposure time, but this, of course, is never true for absorptive systems or mixed systems involving a heat absorption component.

Special devices may be used for cooling localized hot spots. Figure 6 illustrates a liquid metal closed cycle system which transfers a portion of such heat to a normally cooler position where it is radiated from the surface. A similar function may be accomplished by a relatively thick leading edge which conducts heat backward to a cooler position for radiation from the surface. While such systems may not remove all the heat from the local hot spot, they may nevertheless decrease its temperature sufficiently so a desirable material could be used which would otherwise be inadequate. The basic function of these systems is radiative because the heat transfer feature serves only to redistribute the radiative heat load.

We may now consider the applicability of these various types of thermal protection systems to the environmental diagram outlined in Fig. 3. This is presented in Fig. 7. Again, the delineation is not a rigid one but is intended to represent estimates of the most likely areas of application of each of the various systems.

The "Absorptive Systems", based on utilization of the thermal capacity of the structural shell, extend to heat inputs in the range of 1 to 10 Btu. per sq.ft. per sec. for times up to several minutes (lower left corner of Fig. 7). The top of the zone marked "Shell Heat Sink" was delineated by heat capacity calculations based on a skin of high-temperature alloy 0.1 in. thick, limited to a temperature of 1000° F. If the same skin is of aluminum, limited to a temperature rise of 300° F., the top limits of the zone would be correspondingly decreased. Alternately, if the skin is of beryllium of equal *weight,* even though limited to a temperature rise of 800° F., the top limits of the zone would be somewhat increased.

The potential of "Shell Augmentation" devices, such as water cooling, ablation films, and external insulation, is indicated by an increase in flux capability over that of the structural shell in the order of ten times (10 to 100 Btu. per sq.ft. per sec.). The use of water and film ablation devices is preferable to increasing the thickness of the structural shell for thermal purposes, because the effective heat capacity in terms of Btu. per lb. is in the order of two to three times that provided by conventional structural metals. The index of merit for the use of external insulation is its thermal conductivity multiplied by its density (for the case of steady-state temperatures) and a more complex parameter involving also its specific heat for the case of transient heating. The combined insulation and heat absorptive characteristics, "transulation", of external insulation performs essentially the same function as water and organic films for augmenting the heat sink capacity.

For heat fluxes in the range of 100 to roughly 1000 Btu. per sq.ft. per sec. for short exposure (up to several minutes), it may be necessary to utilize intermediate capacity systems such as heavy-wall heat sinks or ablation devices. The situation is shown in Fig. 7 by the area marked "Intermediate Capacity Systems": For high heat flux, in the range of 1000 to 10,000 or more Btu. per sq.ft. per sec., the requirements must be satisfied by using "High-Capacity Systems" based on ablation, sublimation, and transpiration principles.

Continuing with a generalized description of the applicability of thermal protection systems, we shall now consider the place of the radiative systems for exposure times shown in Fig. 7 of 4 min. or more. Collectively, they cover the entire area marked: "Steady-State Heating" in Fig. 3. The specific zones of this region which may be covered by the various radiative systems indicated in Fig. 7 will depend on design factors, and these factors will be discussed in detail in a subsequent section. The zone in Fig. 7 indicated for the liquid metal recirculation cooling system has an upper limit fixed by the metal piping (tungsten assumed as the limit) and a lower limit by the expected availability of simpler radiative systems. In other words, the location is in a range sufficiently difficult to attain by other systems that the complications of the use of liquid metals becomes appealing by comparison! In fact, this last statement can be said to best describe the expected conditions for transferring heat by liquid metal.

Producing for the Supersonic Age

Electroforming a Liner for Mach-6 Wind Tunnel

*By G. E. SUTILA**

The world's largest hand forged aluminum mandrel was used to electroform the nickel liner for a hypersonic wind tunnel at Douglas Aircraft Co. The electroforming process duplicates the contour and finish on the reusable mandrel with high precision, and additional liners can be produced when needed. (L18, G17; Al, *Ni*)

Ideally, the liner for our hypersonic wind tunnel should have been machined from a high-strength material of high thermal conductivity, but this was not feasible because of geometric and physical limitations. Machining the inner surface of a liner to the highly developed contour to create the velocity and flow quality needed would require boring almost 12 ft. deep, down to a 3-in. diameter, with smaller tolerance and higher finish than the usual precision work for a piece of this size.

The electroforming process, employing a reusable mandrel, allowed the machining to be external, where the contour could be more easily generated and checked, and permitted the use of nickel with its high strength and acceptable thermal properties. The mandrel surface was duplicated with exacting precision; similar liners can be made when needed.

The ingot for the mandrel (cast at Alcoa's Lafayette works) was of 2014 alloy, 36½ in. diameter and 78 in. long. Following casting, it was carefully preheated to develop a homogeneous, fine-grained product to insure dimensional stability during machining. The ingot was hand forged at Alcoa's Cleveland works at about 800° F. on an 8000-ton hydraulic press. Heated flat dies were used. The first working cycle gave a thoroughly wrought structure. The piece was then worked on the press until it was shaped roughly to the dimensions required by engineering drawings. In the last step, the forging was laid out and step-sawed to an even closer approximation of the final shape and size required, as shown in Fig. 1.

Following ultrasonic inspection, the rough forging was sent to Hillcrest Crankshaft and Machine Corp., Titusville, Pa., where the outside diameter was rough machined on a 42-in. Niles finishing lathe. The inside diameter was step-bored on a horizontal boring mill. While step-boring of this multiple size hole was exacting, it was accomplished with few difficulties even though the forging was the largest aluminum part ever machined at Hillcrest.

*Supervisor of Operations and Equipment, Aerophysics Laboratory, Douglas Aircraft Co., Santa Monica, Calif.

Fig. 1 — Start of Aluminum Mandrel for Electroforming Process. Ingot of alloy 2014 has been hand forged and step-sawed to approximate size. (Courtesy Aluminum Co. of America)

Fig. 2 — Mandrel After Rough Machining. The inside diameter was step-bored on a horizontal boring mill. (Courtesy Hillcrest Crankshaft & Machine Corp.)

The piece (shown in Fig. 2) was then returned to Alcoa for a thermal treatment consisting of solution heat treatment and artificial aging. It was brought to 935° F., held until all hardening constituents were in solution, then quenched rapidly. This processing cycle dissolves alloying elements and disperses them uniformly in the matrix. Artificial aging at 350° F. for 10 hr. was employed since this treatment resulted in the best combination of properties for alloy 2014-T 6.

The processing sequence and choice of alloy were decided on after a consideration of the requirements for the finished mandrel. Most important, the dimensional stability of the mandrel had to be maintained before and especially after it was finish machined. The specifications on dimensions were so severe that no creep or warpage from residual stress could be tolerated. Thus diametral symmetry in forging, in heat treatment, and in shape was

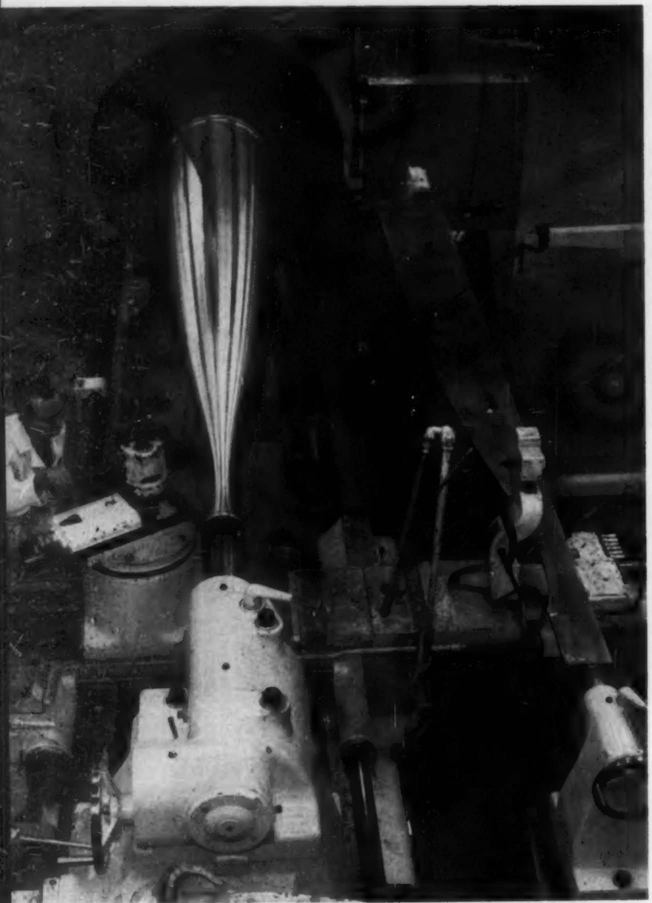


Fig. 3 — Finish Machining of Mandrel on Tracer Lathe Was a Three-Week Job. Templet at right has stylus-bearing surface with a coating of molybdenum disulphide as a lubricant

sought. Hence, the forging was hardened only after rough machining and boring.

Precise Machining Operations

After thermal treatment, the part was again ultrasonically inspected, then carefully packed and shipped to the Torrance facility of Douglas's El Segundo Div. There, on a Sidney tracer lathe, the mandrel was machined to its engineered dimensions — 12 ft. long, 24 in. maximum diameter and 3 in. minimum diameter — and contoured to a high-order mathematical equation.

First, the rough machined piece was finished in the venturi, or throat, in such a manner that the two parts of the mandrel could be separated and withdrawn after the nickel electroforming operation. This joint in the mandrel was of critical importance. The mating surfaces required microfinishing and matching with absolute cleanliness so that, when drawn together and finish machined, no sign of the joint could be detected — this because any infinitesimal opening at the joint would interrupt electroplating at that point.

The two parts to form the throat were joined by running a stainless steel bolt through the smaller part and threading it tightly into a stainless steel insert placed in the larger one. Three dowel pins, through both parts, locked the mandrel parts against rotation.

Twenty-nine uninterrupted machining hours were consumed on the finish cut using somewhat over 0.001 in. lead per revolution at 61 rpm. and 0.0085 in. depth. Total machining time at Douglas starting with the rough machined part was three weeks. The final finish, after slight hand polishing, was 16 micro-in. or better at the throat area and 32 micro-in. or better on the balance of the mandrel. Radius tolerance was 0.001 in. at each of 1440 measuring stations.

The templet for the mandrel was hand finished on a surface table by personnel who were skilled in the precision fabrication of wind tunnel models. Two pieces of aluminum plate, 1 in. thick, mechanically spliced at a prestressed joint made up the templet. The contoured surface was coated with molybdenum disulphide to minimize wear and galling with the lathe follower.

Nickel Plating Takes Six Weeks

Bone Engineering Corp., Glendale, Calif., electroformed the liner and assembled the attachment flanges and the heat exchange system. The latter is a longitudinal copper tubing system to circulate cooling water under pressure. The size of the liner required a vertical plating tank with an agitating mechanism to move the mandrel continuously during the plating cycle. The plating tank and its adjoining pretreatment tank fit into a hole 17 ft. deep. Nickel anodes were suspended from a circular busbar along the periphery of the mandrel during plating. The nickel electroforming solution is specially formulated so that the part produced combines high tensile strength with low residual stress.

Prior to immersion, however, the mandrel ends had been sealed by attaching a gasket to each end, and were held in place by stainless

steel caps. These were secured to the mandrel ends with stainless steel bolts threaded into stainless steel inserts similar to those used at the throat. The mandrel was then put through a pretreatment cycle which included a proprietary etch that cleaned and prepared the aluminum surface for plating and provided for easy separation of the liner.

The electroforming of the nickel part required a high order of quality control of the plating solution. The nickel plating bath was analyzed daily during the minimum plating cycle of 24 hr. a day, seven days a week for six weeks. It is preferable that plating be continuous to avoid adverse laminations which might occur if the operation were interrupted. All plating conditions were controlled within close limits and a daily check was made of the mechanical properties of the deposited metal. This was done by testing sample specimens of the nickel deposit, which were plated simultaneously with deposit going on the mandrel, for ultimate and yield strength, elongation, hardness, residual stress, and purity of the nickel. The tests were made both at room temperature and at the elevated temperatures under which the liner would operate. Bone Engineering Corp. maintained a high degree of purity in the electroforming bath by continuously circulating it through a filtration system.

After the nickel wall was built up to thickness over ⅝ in., the mandrel-liner assembly was stress-relieved and then returned to the original Sidney tracer lathe at Douglas for a cleanup of the external surface and cutting of buttress threads for the attachment into the wind tunnel circuit. Final operations were carried out at Bone. One of these was separation of the mandrel from the nickel liner. This was accomplished by cooling the mandrel-liner assembly to a uniform subzero temperature. The difference in thermal contraction caused the mandrel to separate from the liner.

This nozzle liner, when installed in the Douglas Aerophysics Laboratory, will be used to generate wind speeds equivalent to 4500 miles per hr. This tunnel, though designed for Mach 6 operation, will be capable of reaching Mach 10 with a stagnation temperature of 2200° F. and a pressure of 2200 psi. These same manufacturing steps are being used to make similar liners for Mach 8 and Mach 10 operations except for the addition of a machined beryllium-copper throat.

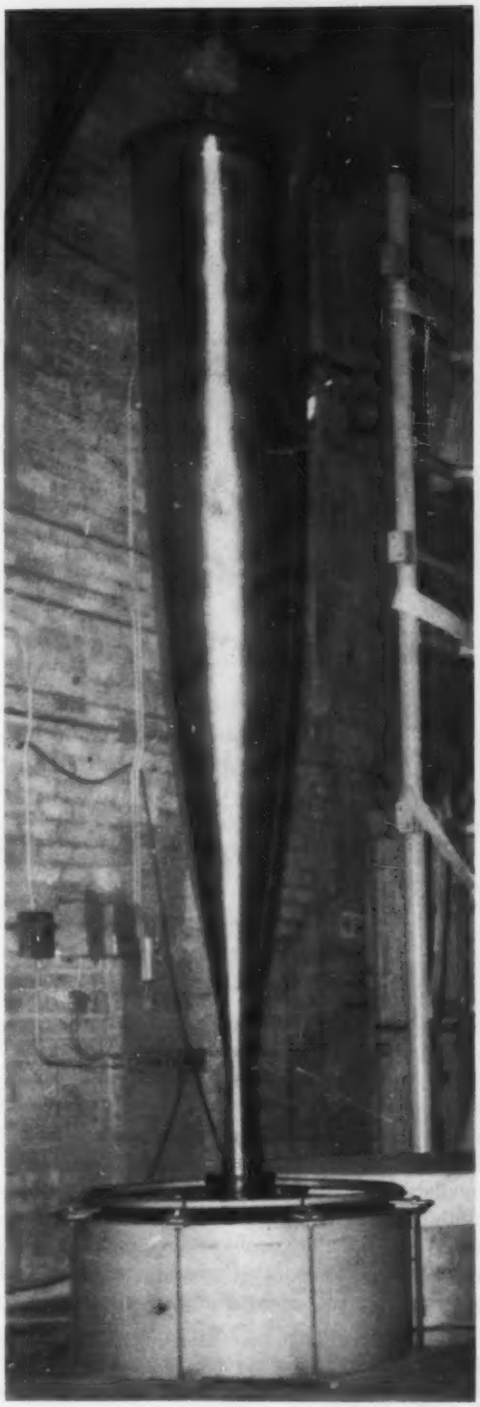


Fig. 4 — Completed Mandrel Is Hung in a Nickel Plating Bath Some 17 Ft. Deep for Electroforming Liner of Nickel ⅝ In. Thick. Nickel anodes hang from circular busbar at top of tank. Plating cycle lasted for six weeks, uninterrupted

Producing for the Supersonic Age

Titanium for Rocket Motor Cases

By J. E. COYNE
*and W. H. SHARP**

Rocket motor cases for solid fuels are now being made from all-beta titanium on an experimental basis. Tests show that the alloy can be readily formed and welded; subsequent aging raises yield strength to over 200,000 psi. Since titanium is much lighter than steel, the ratio of yield strength to density is extremely high. (T2p, Q27a, K1; Ti-b, 17-57)

About a year ago, Pratt & Whitney Aircraft began to look for an alloy with a ratio of yield strength to density of 1,000,000, this figure being the current goal for designers of rocket motor cases. After careful appraisal of the steels and titanium alloys, either commercially available or under development, an all-beta titanium alloy† was selected. Initial data indicated that the alloy could attain a yield strength of 180,000 psi. in cold rolled and aged sheet and strip with tensile elongation ranging from 5 to 10%. With a density of 0.175 lb. per cu.in., it was evident that the alloy was capable of the desired 1,000,000 value. As an example of its potential, the alloy at 180,000 psi. yield strength is equivalent to steel at 280,000 psi., and at 200,000 psi., to steel at 320,000 psi. Strengths in excess of 200,000 psi. are also possible.

Characteristics of the Alloy

The alloy derives its high strength from unusual transformation characteristics. As is known, titanium, like iron, is allotropic, and exists in two crystallographic forms. The room-temperature structure is hexagonal close-packed (alpha); it changes to body-centered cubic (beta) above 1625° F. By introducing vanadium and chromium, normal reversion to the alpha form is suppressed so that the beta phase is retained as the material cools to room

*Mr. Coyne is project metallurgist, Materials Development Laboratory, and Mr. Sharp is Engineering Metallurgist, Pratt & Whitney Aircraft, East Hartford, Conn.

†This alloy was developed by the Crucible Steel Co. of America and supplied by them under the name B-120 VCA. Titanium Metals Corp. of America also supplies this alloy as 13V-11Cr-3Al. Nominal analysis: 13% V, 11% Cr, 3% Al, balance Ti.

temperature, even with slow cooling rates. This structure has moderate strength, accompanied by good ductility. Thus it can be formed readily. Since the beta phase is metastable, it wants to return to the stable alpha form; this return can be achieved by heating at 700 to 900° F. with or without prior cold work. When these conditions are properly controlled, and when the alpha and a compound $TiCr_2$ precipitate in fine and well-distributed form within the grain (and only to a limited extent at grain boundaries), an alloy of high strength and good ductility results.

This alloy has another property of considerable significance. Like other titanium alloys, it has excellent resistance to corrosion under normal atmospheric conditions. The excellent resistance of welded all-beta titanium to salt water has also been confirmed. In considering the long-time storage problems with rocket cases (a pit in a thin-walled casing can be catastrophic), this alloy is the best of all materials which have been under consideration.

Fabricating the Case

The method of fabrication calls for welding forged and machined end closures to a flow-turned cylinder section. In accordance with what is considered optimum design, igniter and thrust termination ports would be integral with the end closure to eliminate the need for welding at such critical locations.

To develop high strength with ductility, the alloy has to be warm or cold worked. In such a condition, it responds to very simple treatment, namely, aging between 700 and 1000° F. for times ranging roughly from 2 to 64 hr., depending upon the aging temperature selected and the degree of cold deformation.

Warm Forging Is Evaluated

To determine whether warm forging would produce a strong ductile structure, billet stock was obtained from Crucible Steel Co., press-forged into pancakes at Wyman-Gordon Co., aged and tested in tension. This material was initially upset at 1800° F., and re-upset at 1400° F., with various reductions ranging from 5 to 44%. Test specimens from the pancakes were aged at 800 or 900° F. for times ranging from 16 to 80 hr. Results of significant tensile tests are shown in Fig. 1. The data demonstrate that high strength with good ductility can be obtained by warm working the material

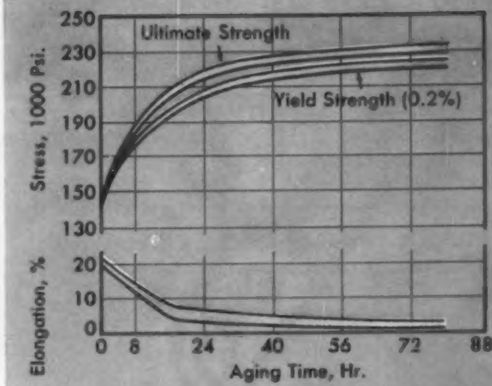


Fig. 1 – Tensile Properties of Pancake Forgings at 70° F. After forging, these pancakes were warm worked 18 to 35% at 1400° F. and aged at 800° F. Aging to achieve adequate properties takes 16 to 64 hr.; compare with Fig. 2

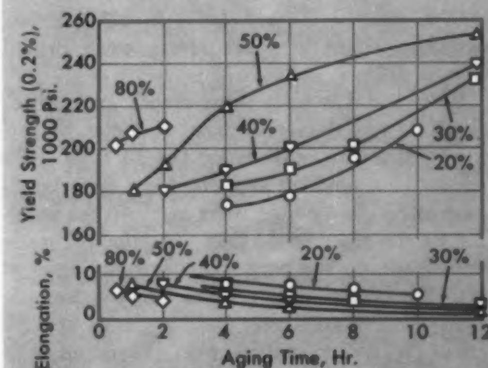


Fig. 2 – Tensile Properties of All-Beta Titanium Sheet Stock Reduced 20 to 80% by Cold Rolling, and Aged at 800° F. Note that adequate properties are produced by aging 2 to 6 hr.

at 1400° F., which is just above the alpha-to-beta transformation range (1250 to 1325° F.).

Because of these promising results, Wyman-Gordon Co. began to determine the forging practice needed to produce comparable properties in large forgings. Billet stock from two material suppliers (Crucible Steel Co. and Titanium Metals Corp.) was upset initially at 1700 or 1800° F. This was followed by additional upsetting operations in the 1400° F. range to obtain pancakes which were 1.2 in. thick. Tensile strengths after aging at 800 or

Table I – Properties of Ring Forgings

	Annealed	Aged at 800° F.		Aged at 900° F.	
		20 Hr.	48 Hr.	20 Hr.	48 Hr.
Tensile strength, psi.	138,900	189,000	219,000	181,500	191,000
Yield strength, psi.	135,200	178,500	207,000	171,000	178,000
Elongation, %	25	8	6.7	10.7	9.4
Reduction in area, %	41	23.7	10.0	22.0	18.0

Table II – Tensile Properties of Hoop Specimens

Reduction	Tensile Strength	Yield Strength	Elongation
34.5%	249,000 psi.	225,000 psi.	4.5%
49.0	260,000	—	4.5
22.4	256,000	215,000	4.0
25.8	242,000	—	8.0
25.8	239,000	—	9.0
23.0	242,000	—	7.0
46.8	245,000	—	3.0
46.8	258,000	—	5.0

900° F. ranged from 201,300 to 225,200 psi., and hardnesses at these levels were Brinell 375 to 415.

The pancakes were subsequently pressed (at 1300° F.) into domes 14 in. in diameter. Heating at this temperature for the 15 to 30 min. needed for pressing did not have any significant effect on the cold work put into the material by the previous forging operation. Tensile tests made on one such dome forging aged at 900° F. gave values as follows: Tensile strength, 177,000 to 213,000 psi.; yield strength at 0.2% offset, 177,000 to 199,000 psi.; elongation, 6 to 8%; reduction in area, 8 to 15%. A second dome forging was aged at 900° F. for 20 hr., finish-machined with a contour-shaped boss, and pressure tested. After repeated pressurizing to 160,000 to 195,000 psi. (temperatures ranging from − 35 to + 135° F.), this dome finally burst at 223,000 psi. at room temperature. Fracture surfaces indicated that ductile failure occurred at a location predicted by design analysis.

Cold Working Improves Properties

As stated earlier, the plan was to make the cylindrical portion of the proposed rocket case by flow-turning a roll-forged ring, and joining the cylinder to the end closures by girth welds. Therefore, work was initiated to determine the properties attainable in material severely cold worked by flow-turning. Sheet stock was cold reduced 20 to 80% by rolling to simulate the flow-turning operation, and aged at 600 to 900° F. Properties of this sheet, shown in Fig. 2, indicate that high strength and good ductility are obtained with an 800° F. age. This temperature appears optimum for severely cold worked material. As comparison with Fig. 1 will show, the aging times required to obtain yield strength levels of 180,000 psi. with 5% minimum elongation are considerably shorter for cold worked sheet (2 to 6 hr.) than for warm worked forgings (16 to 64 hr.). Note that yield strengths over 200,000 psi. are attainable.

The roll-forged rings which were used to evaluate flow-turning were produced by Ladish Co. As shown in Table 1, the rolled rings were found to have excellent properties as annealed, the prior condition required for the severe cold working needed to produce a flow-turned cylinder. The response of these rings, as roll-forged, to aging for varying times at 800 and 900° F. indicates that internal stress will be retained in the rolled ring. Obviously, one would anticipate high strengths in cylinders flow-turned from such stock.

Cylinders were flow-turned with reductions from 22 to 49%. After hoops were machined from the cylinders and stressed by hydraulic loading, tensile properties were determined. Results (after aging at 800° F. for 7 hr.) are listed in Table II, which demonstrates that yield strengths in excess of 200,000 psi. with good elongation are attainable in flow-turned cylinders of this alloy. The results are highly encouraging inasmuch as these yield strengths are of the same order as those of the better high-strength steels. This is significant because the density of beta titanium is only 65% that of steel.

Preliminary evaluation of the alloy's notch sensitivity shows it to be similar to that of the high-strength steels currently in use in rocket motor cases at the 200,000-psi. yield strength level.

Fig. 3 — Bulge Test of All-Beta Titanium Showing Ductility of Parent Material and Weld in As-Welded Condition

Sound and ductile girth welds are essential for a rocket case. Pratt & Whitney Aircraft design calls for the metal sections next to weld areas to be beefed up in weight by some 25 to 50%. Weld beads are intended to be near flush on the outside diameter, and convex on the root side. The bead runs about 20% thicker than the adjoining parent metal.

In the preliminary work, test panels were fusion welded with parent metal filler, and subjected to tensile and bulge tests. According to tests, this welded sheet possessed properties that were comparable to properties of annealed sheet. Weld strength was considerably improved by cold working the weld before aging. Accompanying the strength increase, of course, was a very definite loss in ductility. While cold working of a full-scale circumferential weld may be feasible, it seems easier to produce full-scale welds which are sound, soft and ductile. Figure 3, a photograph of a bulge test specimen, illustrates that the alloy, as welded, can be appreciably deformed before rupturing.

Fusion welds lose bend ductility and "bulgeability" when postweld stress-relief treatments of 1300 to 1500° F. are employed. Though this loss of ductility is readily apparent, stress-relieved welds in all-beta titanium still possess better bend ductility than welds in other titanium alloys.

Residual tensile stresses as high as 22,000 psi. have been measured in pilot pressure vessels (9.4 in. diameter) in the as-welded condition. Based on behavior of these vessels under hydraulic tests, the present intention is to leave welds in the full-scale case in the as-welded condition since they are more ductile. If, however, residual stresses in full-scale weldments are excessive, it may be desirable to stress-relieve the weld by local induction heating.

Pilot Vessels Are Tested

Pressure vessels, 9.4 in. diameter, were made from hydroformed and flow-turned (cylindrical section) sheet stock, and welded by the inert-gas shielded-arc process in an argon-filled chamber to protect from contamination. These pilot vessels were then tested in the annealed, as flow-turned, and flow-turned and aged conditions, with welds being left either as-welded, or locally stress-relieved. A typical failure is shown in Fig. 4. Bursting stresses have ranged from 61,000 to 260,000 psi. (stress based upon thin flow-turned cylindrical section). Bursting stresses have been low when failures have originated in the circumferential welds. As welding technique has improved, failure origins have moved into the thin-walled parent metal. Twelve of the last 16 pressure vessels resisted stresses over 200,000 psi. before bursting. Highest stress achieved: 260,000 psi. Several pressure vessels have been tested under cyclic conditions (3 min. at load) at stresses over 180,000 psi. at − 35, + 70 and + 135° F.

Subsequent microscopic examinations indicated that coarse grain size (0.060 to 0.080 in. diameter) is associated with the low bursting strength of the first series of tests. By modifying welding procedure (most significantly, by cooling the molten weld metal with helium gas), welds of finer grain size were obtained. This helium-cooled weld, as Fig. 5 shows, is free from a rather severe centerline condition present in the coarse-grained weld.

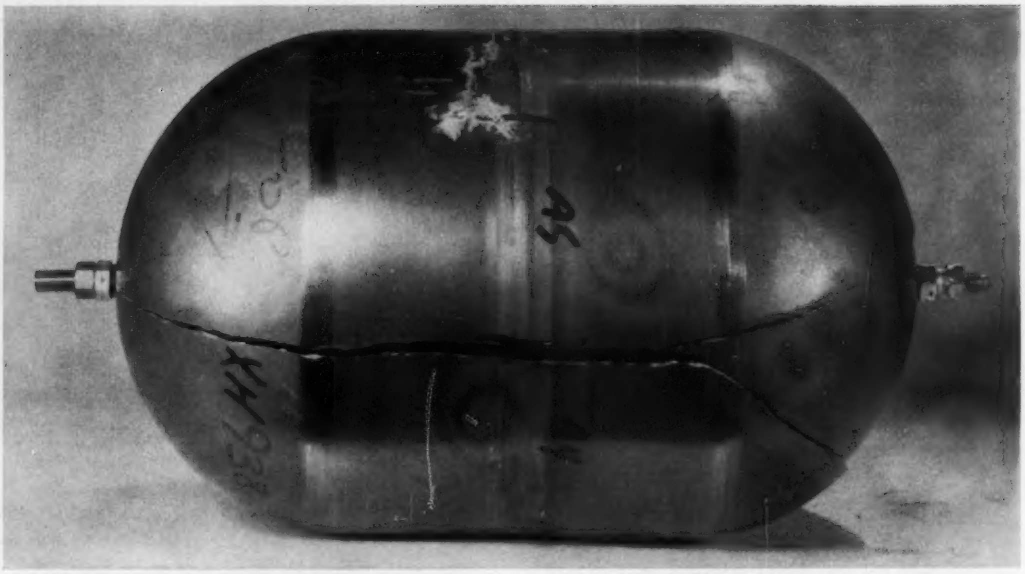


Fig. 4 — Burst Failure in Pilot Vessel Produced From All-Beta Titanium

Welding Is the Key

This alloy is not simple to weld. In fact, the welding of any titanium alloy can be troublesome, since titanium welds are easily contaminated by oxygen and nitrogen from the air. Such contaminated welds crack readily, and are very difficult, if not impossible, to repair. All-beta titanium does not differ from the other titanium alloys in this respect. Based on the welding of some 25 pilot pressure vessels and numerous test cylinders, we believe that sound, fine-grained welds are a practical possibility. Upon the success of the welding will hinge the success of the rocket case constructed from all-beta titanium.

Fig. 5 — Microstructures of Welds in All-Beta Titanium. The coarse grains on the left were associated with low bursting strengths in pilot pressure vessels. When molten weld metal was cooled with helium gas, finer grain results, and bursting strengths exceeded 200,000 psi.

Tension Test for Thin Sheet Steels

*By GLENN E. SELBY**

In making tensile tests from sheet steel 0.01 in. or less in thickness, great care is needed. This article outlines procedures for making and testing such specimens. (Q27, 1-54; ST, SS, 4-53)

ADEQUATE test specimens are of utmost importance if good tension test results are to be obtained in thin sheet steels. To achieve this, several steps are necessary. First, coil samples without kinks, breaks, pock marks and other defects should be selected. This requires careful handling of sample preparation. Next, test specimens should be cut on a sharp shear with the blank width held constant.†

The Armco tension test specimen shown in Fig. 1 is used for this type of testing. This specimen has a blank width of 13/16 in. (or ⅞ in.) and is milled to a width of 0.750 in. Then, the reduced section is machined, with the vise of the milling machine holding the pack of test specimens.

However, if the milling instructions listed below are followed, satisfactory test specimens can be machined in which only the reduced section is milled. Figure 1 illustrates this type.

Milling Practice for Thin Steel

The cutter is high speed toolsteel, 3 to 3½ in. diameter. It has 10 to 16 teeth, a 45° helix angle, clearance of 0.001 in. per 1/32 in. of land, and must be ground before each group of specimens. Cutters are supplied by Gorham Tool Co., Brown & Sharpe or Goddard & Goddard.

For back-up material, use cold rolled steel ¼ in. thick or thicker. The surface must be smooth! As for cutting depths and speeds for reduced section (from 0.750-in. blank), with annealed material, the first cut is 0.120 in. at 3¼ in. per min. feed (130 rpm). Then the cut is finished at 0.005 in. (1¼ in. per min. feed, 130 rpm.).

Hardened material is cut differently. The first cut is 0.120 in. at 3¼ in. per min. feed (43 rpm.), and the finish cut is 0.005 in. at 1¼ in. per min. feed (100 rpm.). If satisfactory finish cannot be obtained on the hardened materials, carbide-type cutters can be used. Specifications are: 4 in. diameter, six teeth, 25° helix angle, clearance of 0.001 in. per 1/32-in. land, and cutter should be sharpened before use. Such cutters are supplied by Sonnet Tool Co. Samples should be checked for pock marks or

*Senior Metallurgist, Research Laboratories, Armco Steel Corp., Middletown, Ohio.

†The O'Neil-Irwin Mfg. Co., Lake City, Minn., makes a special shear for this purpose: DI-ACRO shear No. 3 Code DIELM cuts up to a 12-in. width of 16-gage material.

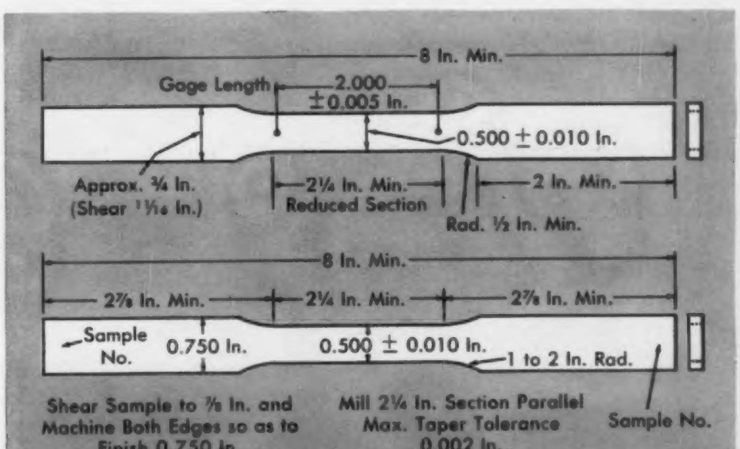


Fig. 1 – Diagram Shows the Armco Tensile Sample No. 35 for Sheet Steel (Bottom). Also shown is the alternative, a standard rectangular test, A.S.T.M. Designation E8 (top)

any dents that may result from milling chips.

For Armco 17-7 PH or PH 15-7 Mo stainless steels, the following procedures are used for Conditions TH 1050 and RH 950. First, clean in carbon tetrachloride* or some suitable solvent or vapor degreaser. (This will remove oil, grease, and drawing lubricants.) After this, scrub mechanically with mild abrasive cleaners, Oakite No. 33 or similar proprietary cleaners. This is necessary to remove dirt or other insoluble materials. All traces of cleaner should then be removed by rinsing thoroughly in warm water. Handle carefully at all times. Bind pack with stainless steel wire between back-up strips of 17-7 PH or PH 15-7 Mo stainless steel, 0.030 in. or heavier and ¾ to ⅞ in. wide.

For Condition TH 1050, transform at 1400° F. for 90 min., cool to 60° F. within 60 min., and hold at 60° F. for 30 min. minimum. Harden at 1050° F. for 90 min. and air cool.

For Condition RH 950, heat at 1750° F. for 10 min., and air cool to room temperature. Cool to − 100° F., hold for 8 hr., harden at 950° F. for 60 min. and air cool.

Since it has been shown that even the best milling techniques (outlined previously) will produce small burrs that are detrimental to test results, the edges and shoulders of the parallel sections should be hand polished to remove all burrs. Extreme care must be taken not to bend, kink or scratch the samples. The most satisfactory procedure has been to place the test specimen on a smooth, flat surface with the edge of the parallel section coincident with the edge of the surface, and polish. This should be done with long smooth strokes using No. 1 emery paper. Maintain edges of the parallel section at right angles to the sheet surface. Avoid tapering of the edge into the sheet surface and polishing of the sheet surface. A properly prepared specimen will have only a slight chamfer on the edge with little or no scratches on the sheet surface, and width will have been reduced about 0.002 in. from the milled width.

For the test specimen just described, the width is measured along the gage length by ordinary hand micrometers and the minimum width is recorded to the nearest 0.001 in. Thickness is measured along the gage length, and the minimum thickness recorded to the nearest 0.00002 in. Naturally, hand micrometers, even with verniers, are not suitable for this. Sheet surfaces should be cleaned of oil films and dirt before measuring for thickness. Carbon tetrachloride has proved most satisfactory for this purpose; other solvents do not consistently remove all traces of oil or grease.

*Avoid breathing fumes and prolonged contact on skin. Use with hood or adequate ventilation.

The gage length is marked off by scribing marks 2 in. apart with a sharp pencil. Be careful not to mark the specimen deeply, and thereby cause breakage. Scratching with a scribe or punching is not recommended.

Testing the Specimens

A testing machine with 5000 lb. capacity (such as a Baldwin-Lima-Hamilton P.T.E. type) offers a range of loads suitable for this type of testing. Specimens should be lined up carefully in the machine to insure axial pull during the test. Uniform gripping is also required. This had led to grips of special design which are now being used successfully at Armco Research Laboratories for testing 17-7 PH in all gages. For material under 0.010 in. the specimen must be handled and the grips must be tightened in such a way that there is no twisting. With patience and proper use of the grips, this can be done satisfactorily. Specimen edges should be checked for uniform gripping across the width before final tightening of the preload grips.

One-Piece Extensometer

The Armco one-piece stainless steel extensometer can be used satisfactorily on this thin material. Place the extensometer carefully and attach it firmly in the center of the parallel section of the specimen without bending or nicking its edges. Sometimes it is necessary to determine the tensile strength and elongation on a specimen different from that used to determine the yield strength, since marking of the specimen by the extensometer may cause an early tensile failure with subnormal elongation. (This extensometer is not available commercially at present.)

In conclusion, test results should be averages of a minimum of two tests when thicknesses are 0.005 in. and above. Five or more tests should be averaged when thicknesses are 0.001 to 0.004 in. Test values that are obviously low due to premature breakage should not be averaged.

It must be remembered that this type of tension testing is more time consuming than the ordinary heavy-gage test. Armco experience has shown that 15 to 20 min. is needed for the proper preparation and testing of each sample after it has been milled.

Which Bell Furnace?

*By L. W. JOHNSON**

Selecting the proper bell furnace for a specific application can be difficult. This article, which gives the general characteristics of the three types of bell furnaces, should be a serviceable guide to the heat treating specialist. (W27j)

INCREASINGLY STRINGENT REQUIREMENTS for heat treating and brazing cycles pose complex equipment problems for aircraft and missile makers. Sizes and shapes of parts to be brazed or heat treated vary over a tremendous range. Complicating the problem (in the development phase, particularly), the work must often be done in existing furnaces because there is insufficient time to purchase and install new furnaces.

For these reasons the versatile bell furnace is very popular. Minimum fixturing is required when brazing because the work does not have to be moved during the brazing cycle. Furthermore, the bell furnace normally can accommodate a wide variety of sizes and shapes of work, a wide variety of heating and cooling cycles, and a wide variety of atmospheres.

However, all bell furnaces are not alike, some being much more versatile than others. While a determined missile engineer generally gets what he wants out of the bell furnace, the cost of the ingenuity, special gadgetry and damage to the furnace may be higher than the installed cost of the right furnace. However, time schedules frequently will not permit purchase and installation of the right furnace.

The obvious answers are to have at least one extremely versatile furnace, and try to anticipate future requirements when a furnace is purchased. Factors that affect versatility are: size, maximum temperature rating, temperature uniformity, maximum heating rates, maximum cooling rates, and atmospheres (including vacuum) that can be used.

One type of furnace now coming into prominence because of high-temperature requirements is the cold retort furnace. A major heat barrier exists in furnaces used for treating components for high-speed aircraft and missiles. Manufacturers in this field are continually bumping their heads on the barrier imposed by hot retort furnaces. Many of the processes involved in the manufacture of high-speed aircraft and missiles must be done either in vacuum or in a carefully controlled atmosphere. Since minute quantities of moisture or an improper gas can ruin the work, it must be enclosed in a tightly sealed container. Normal practice has been to place the work in a sealed retort. Then the retort is put in a furnace, or the furnace is placed over the retort. For long heating cycles at relatively low temperatures this is acceptable. However, for higher temperatures and shorter cycles, this hot retort becomes a serious impediment.

The cold retort furnace (Fig. 1) removes this heat barrier. However, because of their relatively high initial cost, some people who should be using radiation shield furnaces are not using them. Actually, a radiation shield furnace may be a sound investment for operations in the 2100 to 2300° F. range. Furthermore, if higher temperatures are anticipated, the radiation shield furnace is a "must".

In this furnace, the outer walls become the retort while the heating units are inside with the work. A series of radiation shields or baf-

*Industrial Heating Dept., General Electric Co., Shelbyville, Ind.

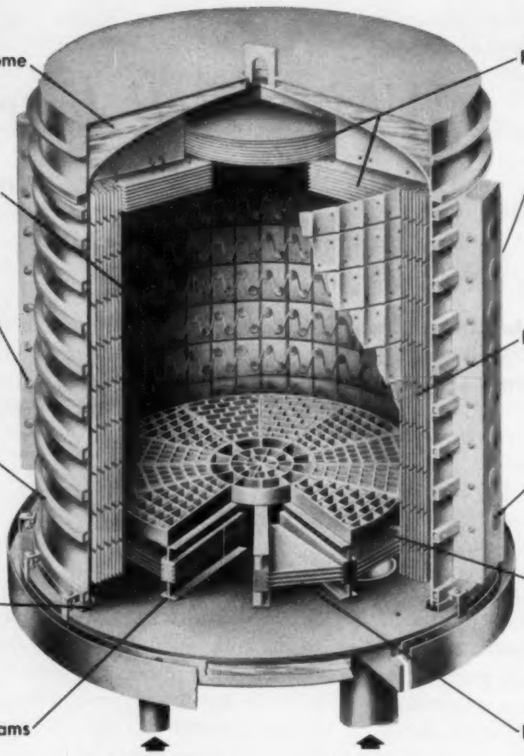


Fig. 1 — Radiation Shield Furnace. Heating elements used inside shield make retort unnecessary. Though first cost is higher, economies in operation often make up for it

fles is placed between the heating elements and the outer wall to cut down on heat losses. This type of furnace, of course, has higher heat losses than a conventional brick-insulated furnace but it gives some very real advantages.

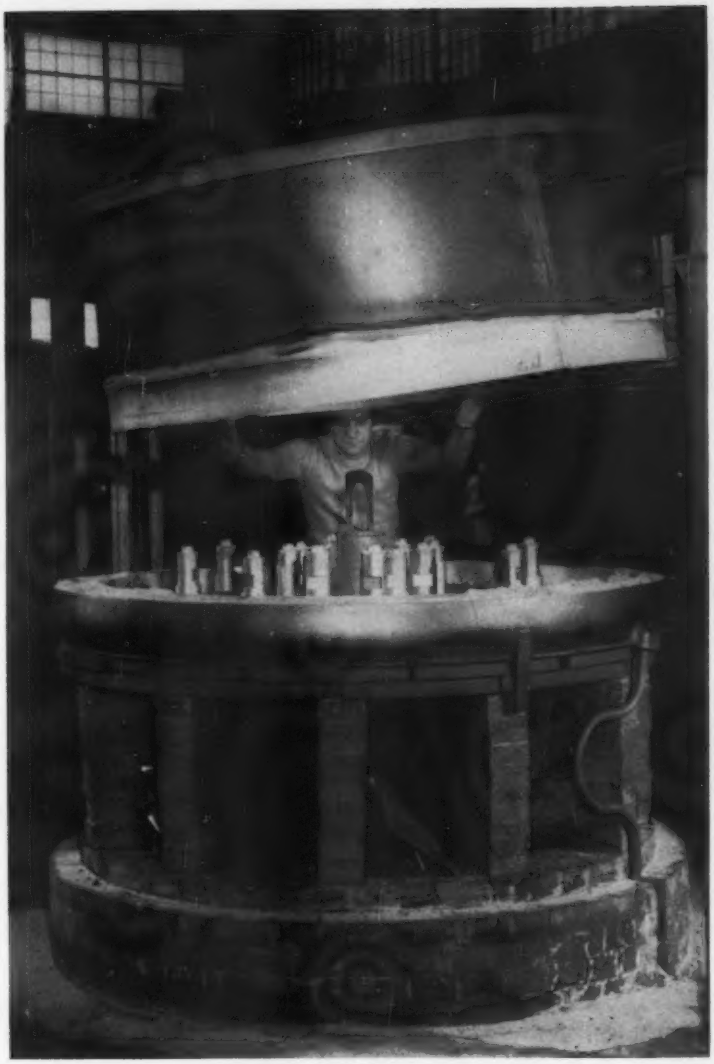
First of all, we eliminate the hot retort which is a replacement item. Though the cost of replacements can be controlled by limiting the maximum operating temperature, using care in furnace operation and retort handling, careful selection of retort materials and design, and regular and careful retort maintenance, retorts must still be recognized as expendable parts. Provisions must therefore be made for maintenance and replacement, and spares must be available.

On the other hand, the life of all components in the radiation shield furnace should be excellent if the furnace is used at or below its rated temperature. The cold walls act as the retort to contain the protective atmosphere or vacuum. The radiation shields are subject to very little stress except from thermo cycling. Since they are broken up into a number of small sheets, the cumulative effect of thermo cycling is minimized. Heating units are molybdenum rods which are rated as high as 3100° F., and are now being applied at higher temperatures. The load grids are the only hot metal which must withstand any appreciable loading.

Heat Barrier Removed

Secondly, we have eliminated the heat barrier between the work and the source of heat or cooling. In the hot retort, heating and cooling rates are definitely limited by the rate at which heat can be transferred through the retort. Though the slow cooling rates (particularly below 1000° F.) can partially be compensated for by using multiple bases and retorts with a single heating furnace and by using a forced convection cooling bell, it is difficult to get the cooling rates normally desired when working with high-temperature metals. There

Fig. 2 — Furnace With Refractory Pier Base. Retort cover is being removed from sand seal to expose work load. High piers allow uniform heating on the bottom as well as at the top and sides. This type of furnace has the lowest first cost, but its application is somewhat limited



is little than can be done about the slow heating rates except to use a proportioning control (rather than an off-on control) so that the retort is maintained at maximum allowable temperature throughout the heating cycle.

In the radiation shield furnace there is no barrier between the heating units and the work. Since the molybdenum rod heating units can be operated as high as 3100° F., substantial heat head between the heat source and the work is possible. Heating units are in the same protective atmosphere as the work; therefore, molybdenum (or tantalum, or tungsten) heating units, which can operate at high heat densities and still retain their physical strength can be used. With these metals, the furnace can have a heat rating of two or three times the rating possible with heating elements which operate in air.

In a radiation shield furnace, rapid cooling rates can be provided by a cooling system which allows rapid circulation of an inert atmosphere. The walls through which the cooling gas must be introduced are cold, so vacuum-tight piping connections are relatively easy to make and maintain.

In a hot retort furnace, with its brick-lined heating chamber, the total mass to be heated, other than the work, is normally rather high. The radiation shield furnace has no hot retort which must be heated, and insulating shields are made as thin as possible to reduce the effects of thermo cycling. Therefore, the total furnace

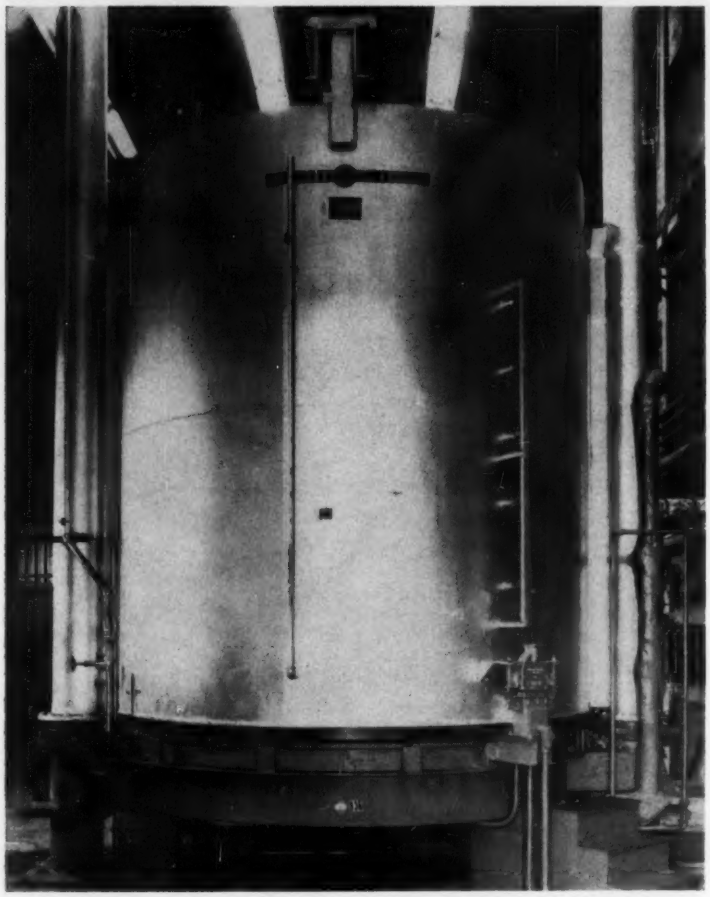


Fig. 3 — Bell Furnace With Metal Dome. This furnace is used to heat treat jet engine components at 2000° F.

mass to be heated, or cooled, is very low compared to a retort-type furnace. This allows the furnace to be heated or cooled very rapidly.

To summarize, from the operating standpoint, the radiation shield furnace not only raises the temperature limitations and allows operation in vacuum, but allows much shorter and more flexible heating and cooling cycles.

Economics Also Important

A radiation shield furnace equipped for 2250° F. operation, but suitable for modification to 2600° F. operation, with a vacuum system capable of evacuating to 1/10 micron in about 30 min. will cost about double the price of a hot retort furnace suitable for operation at 2150° F. with a hydrogen atmosphere and equipped with two bases and two retorts. In most installations, a single radiation shield furnace should be able to do as much work as a hot retort furnace with two bases and retorts. Thus, much less floor space would be needed.

The shorter heating cycle and the lower furnace mass of the radiation shield furnace will be overbalanced by the higher wall losses. Therefore, the energy costs will probably be about twice as high for this furnace as it would be for a hot retort furnace.

However, a radiation shield furnace will need less atmosphere gas. When operated as a vacuum furnace with inert gas cooling, one volume of inert gas will be required for the cooling cycle. When a radiation shield furnace is used with hydrogen, it will normally be used at an absolute pressure of less than 1 mm. of mercury (atmospheric pressure 760 mm.). As compared to a retort-type furnace, the same number of volume changes of atmosphere would require 1/760 as much hydrogen.

In a retort furnace and a radiation shield

Bell Furnaces for Heat Treating and Brazing Above 1900° F.

<table>
<tr><th></th><th>REFRACTORY PIER BASE</th><th>METAL DOME</th><th>RADIATION SHIELD</th></tr>
<tr><td>Maximum temperature rating</td><td>2050 to 2300° F.</td><td>2050 to 2300° F.</td><td>2300 to 2600° F. and higher</td></tr>
<tr><td>Temperature uniformity</td><td>Fair (a)</td><td>Excellent</td><td>Excellent</td></tr>
<tr><td>Speed of heating to uniform temperature</td><td>"Thermal inertia" of base slows uniform heating of load</td><td>Low thermal inertia and low losses of dome base allow rapid, uniform heating</td><td>Low thermal inertia of supports allows rapid, uniform heating</td></tr>
<tr><td></td><td colspan="2">Hot retort forms barrier between work and heating units—slows heating rate</td><td>High heating rates can be achieved</td></tr>
<tr><td></td><td colspan="2">Though speed of heating may be slow, it may be doubled by using molybdenum heating elements</td><td>Molybdenum heating units standard</td></tr>
<tr><td></td><td colspan="2">Brick-lined heating bell heats and cools slowly. This is usually used to advantage by maintaining heating bell hot and removing from load for cooling</td><td>Furnace can be heated and cooled rapidly. More power is required for heating</td></tr>
<tr><td>Maximum cooling rates</td><td colspan="2">Hot retort forms barrier between work and cooling medium in normal operation</td><td>Furnace and load cool rapidly when power is shut off</td></tr>
<tr><td></td><td>Thermal inertia of refractory pier slows cooling</td><td></td><td rowspan="2">Because a cold outer wall forms the "retort," it is relatively easy to circulate a cooling gas through the furnace or introduce a coolant such as liquid carbon dioxide</td></tr>
<tr><td></td><td>Seal (b) (normally sand or welded seal) is located in heated zone near work</td><td>Seal (c) (metal-to-rubber gasket) is located outside of heating zone well below work</td></tr>
<tr><td>Atmospheres (hydrogen, helium, argon)</td><td>Being used successfully</td><td>Satisfactory</td><td>Atmospheres can be used at low pressures</td></tr>
<tr><td>Vacuum purge</td><td>Sand seal not satisfactory; welded retort satisfactory</td><td>Satisfactory</td><td>Normal</td></tr>
<tr><td>Vacuum operation</td><td>Not normally built for vacuum operation</td><td>Retort seal is satisfactory for vacuum operation</td><td>Normal</td></tr>
<tr><td>First cost</td><td>Basic design is lowest first cost</td><td>Basically only slightly more expensive than refractory pier furnace</td><td>Most expensive because of large vacuum system and expensive high-temperature metals used</td></tr>
</table>

(*a*) High "thermal inertia" of refractory base makes the bottom heat and cool more slowly than the higher portion of the load.

(*b*) With forced-convection cooling, the seal projects near the work area and disrupts cooling flow patterns. A sand seal does not allow liquid spray cooling, and a welded seal would have to be carefully prepared to withstand liquid spray quenching. Coolants must be introduced and removed through pipes welded to the retort bottom. These welds do not last many cycles.

(*c*) With forced-convection cooling, streamlined air flow around the retort can be obtained. Metal-to-rubber seal allows liquid spray cooling. Coolants such as liquid carbon dioxide can be used inside the retort.

furnace, atmospheres must be changed during the cycle to remove water vapor formed when hydrogen reduces surface oxides. Higher diffusion rates of water vapor through total volume of hydrogen at lower pressures allows more efficient removal of water vapor from the vicinity of critical surfaces at low pressures. Therefore, substantially less hydrogen is required.

The radiation shield furnace will require substantially less expenditure for replacement costs. In addition to having no retort replacement, the heating elements will have a substantially longer life expectancy.

When the engineer starts to select a bell furnace for an application, he must take all of the various factors which were previously discussed into account. To aid in his decision, the characteristics of each type of furnace have been tabulated. By referring to the table, he can match these characteristics with the job he is trying to accomplish, and arrive at the correct bell furnace for his needs.

ASM's President for 1959-60

Walter Crafts
Associate Director, Technology
Metals Research Laboratories
Union Carbide Metals Co.

In 1929, just a few years out of college, Walter Crafts joined the staff of the Union Carbide and Carbon Research Laboratories, then in Long Island City. He has been associated with these Laboratories ever since, and was appointed chief metallurgist in 1946. At present, he is associate director, technology, of the Laboratories, which have been renamed the Metals Research Laboratories of the Union Carbide Metals Co.

He graduated from Yale University in 1924 with a B.A. degree, and won his M.S. in 1926 from Massachusetts Institute of Technology. His only experience previous to Union Carbide was with the Illinois Steel Co. as a metallurgist.

It was the good fortune of some of us to become acquainted with Walter during these early years. One day at a quick lunch in a Long Island cafeteria, Walter mentioned in his characteristically quiet offhand manner that the food tasted pretty much like that served on a cattle boat that carried him to England one summer while he was attending Yale. His description of tending the cattle during the voyage was vivid and down to earth. One of his listeners asked, "Walter, why in the world did you ever take a trip like that?" His answer was simple and direct. "All I wanted to do was see what a cattle boat was like, and learn what England was like." This simple story clearly expresses his will to acquire knowledge of things unknown and unusual.

Since 1929 Walter Crafts has been conducting – either personally, by supervision, or in a directive capacity – work connected with basic and applied research in the physical metallurgy of alloying steel to improve its utility. His underlying philosophy has been to establish the chemical processes of steelmaking on a scientific basis so they could be well understood by the metallurgical profession.

The early work of the pioneering metallurgist, Charles Herty, involving the combined use of manganese and silicon to improve steel quality has been greatly extended through the work of Walter Crafts. The knowledge thus gained of the relationship between the deoxidizing reactions and equilibrium in the steel furnace has been helpful everywhere steel is melted.

Walter Crafts' work on the physical metallurgy of stainless steels, particularly those of low carbon content, has been of great importance. In cooperation with G. W. Healy, H. P. Rassbach and D. C. Hilty, his detailed studies of the chemical reactions associated with decarburization, oxidation, and subsequent refinement of this highly specialized type of steelmaking practice are outstanding. These studies are well documented in the technical literature, and have provided a good basis for the low-cost process using oxygen to produce low-carbon stainless steels.

Almost parallel with the work on physical chemistry have been investigations before and during World War II on the design of high-strength low-alloy steels. He and his co-worker, John L. Lamont, were among the first to recognize the significance of the Grossmann hardenability theory. Their work helped apply that theory and lay the basis for the low-alloy "National Emergency" steels which served so well during World War II. A product of this work is a standard textbook, "Hardenability and Steel Selection", by Crafts and Lamont.

One of the best measures of the accomplishments and caliber of a professional man is the recognition he receives among his contemporaries. With D. C. Hilty, he received the A.I.M.E. F. L. Toy Award for 1953, which recognizes the best original contribution on any phase of openhearth steel melting practice. He was co-author with A. B. Kinzel of the first volume of the Alloys of Iron Monograph series entitled "Alloys of Iron and Chromium".

Walter Crafts has been granted about 25 United States patents covering steel compositions, addition agents for steel, and methods of treating molten metals. They include low-alloy and high-alloy steels, electrical sheet steels, malleable iron, deep hardening boron steels, deep drawing steels, chromium steels, magnetic materials, and nickel-base alloys. His outstanding aim has been to make a science out of the art of steelmaking, and his successes in this direction justify the high regard which the metallurgical profession holds for him.

Walter approaches his hobbies with the same desire for understanding and intellectual stimulation that he brings to his work. He has made a study of cyclical behavior in nature, and has a collection of rare old maps, as well as portraits and biographies of great pioneers in metallurgy. To gain a better appreciation of music, he has made a study of the clarinet. He is an accomplished wood carver and a better-than-average photographer.

Years ago Walter acquired a cottage on Lake Catchacoma, north of Peterborough, Ont., where he could relax in the company of his wife, Sue, daughter, Suzanne, and son, Walter. This part of Ontario, of course, is synonymous with good fishing, and Walter attributes much of his skill in this sport to his careful study of the construction and behavior of tackle.

Walter has been chairman of the Buffalo Chapter of the American Society for Metals, has served on several national A.S.M. committees, and is now the Society's painstaking and hard-working president. He carries on the tradition of vision and long-range progressive planning on which the Society has grown. To give only one example, as a member of the Board of Trustees in 1955, he fostered and encouraged the Society's experiments in mechanized literature searching which are pointing the way to solution of one of the country's most pressing problems and have come to fruition in the Society's newest service – metals documentation.

Russell Franks

Temperature Control During Induction Heating

*By JOSEPH F. LIBSCH**

Though induction heating is extremely rapid in most applications, control is often necessary for desired results. As a consequence, several types of fast-acting controls have been developed to monitor critical processes such as the growing of germanium crystals for transistors. Some of these systems are described in this article. (S16, J2g)

More exacting heat treatment specifications and an emphasis on automatic control have developed a need for direct measurement and control of the temperature of a part being heated by induction. The precise control of temperature needed in growing single crystals of germanium for transistors is a good example. Successful and uniform results in hardening, tempering and other heat treating operations likewise depend fundamentally upon accurate temperature control.

Before suitable sensing and control devices were developed, most induction heating operations were controlled indirectly. For example, mechanical or electrical timers were used to reproduce a given time cycle determined by previous metallurgical analysis. Providing that the power output from the induction heating generator, the workpiece-coil relationship, and other factors are maintained at reasonably constant values, such timers control the temperature adequately in applications where temperature is not extremely critical. A large number of hardening, tempering, brazing and soldering operations in which induction heating is used continue to be controlled by timers.

However, when line voltages fluctuate or a variation occurs in the position of the workpiece within the coil there will be some change in the temperature of the part being heated in a given time cycle. Furthermore, the indirect approach previously described requires extended setup time. Sometimes, also, several parts must be destroyed to determine the proper time cycle. More important, this approach does not permit automatic temperature control in applications where the part must be maintained at temperature for a long time or where parts are heated continuously.

Recently, new sensing elements, very high-speed controlling or recording instruments (or both), and a number of unique power proportioning control systems have been successfully combined to provide direct temperature measurement and temperature control on parts heated by induction. Some of these new methods are described in this article.

Factors to Consider

All temperature control systems for induction heating require a measuring or signal element (to indicate the temperature of the work), a controller (to compare the temperature of the work with a preset desired temperature), and a power control device (to regulate the power of the induction generator). In induction heating, the principal problem occurs in providing sensing and control devices which act rapidly enough to keep up with the very rapid rates of heating. Rates of 200 to 1000° F. per sec. are frequently encountered. To meet such rates, both sensing and control elements must respond in minimum time. This generally

*Professor of Metallurgy, Lehigh University, Bethlehem, Pa.; Consulting Metallurgist, Lepel High Frequency Laboratories, Inc., New York.

limits the application of standard temperature measuring and control equipment. Fortunately, suitable equipment is now available to accommodate these rapid heating rates.

Adaptation of Thermocouples

Fine wire thermocouples may be used successfully to indicate the temperature in induction heating applications. Best results have been obtained when the individual elements of the thermocouple are percussion welded (about 1/16 in. apart) to the surface of the part to be heated. The thermocouple wires are electrically insulated from the coil turns by a small-diameter, two-hole, ceramic insulator. Fine wires (0.010 in. diameter for a Chromel-Alumel couple) are used because they are not overheated excessively by induced energy. They also respond rapidly. Naturally, the electrical signal from the thermocouple may be readily used in the subsequent control functions.

While different types of couples may be used for different temperature ranges, the user must make sure that these couples of fine wire do not deteriorate. This can easily happen when they are operated at elevated temperatures for long periods of time. Furthermore, to be successful, thermocouples must be attached to the part being induction heated. Unfortunately, welded thermocouples have not proven useful where the parts have to be rotated or progressed during heating.

Radiation Devices Are Useful

Special radiation sensing elements have been developed for induction heating. These units provide effective signals even when the target is as small as 0.100 in. in diameter. The radiation head is placed 4 in. (or more) from the coil and sighted on the surface of the work through an opening between the coil turns. Rapid response is obtained by substituting a single thermocouple junction for a thermopile having eight or more junctions. Such radiation units follow extremely rapid temperature changes. Where water vapor or fumes might interfere with sighting, they are dispersed with a stream of air or gas.

Radiation sensing elements are most effective above 1200° F. Recently, however, units which can be used at considerably lower temperatures have become available. Since no actual contact is required between the sensing element and the workpiece, this technique can be used in production. Also — unlike the thermocouple method — it permits rotation or progression of the part through the coil.

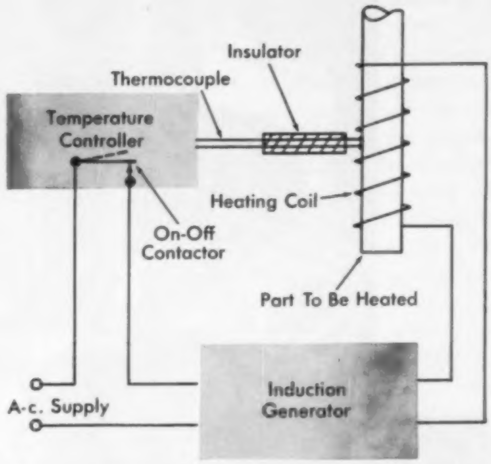


Fig. 1 — Controlling the Temperature With a Thermocouple Arrangement. The thermocouple signal is fed to the high-speed controller which determines the variation from the preset temperature. When this temperature is reached, the on-off contactor turns the generator off. In this setup, a radiation sensing element can also be substituted for the thermocouple; this eliminates the need for direct contact with the part being heated

Where significant changes in emissivity occur during heating or holding at constant temperature (because of oxidation or scale formation, for example), close temperature control is not possible. Special arrangements are needed for measuring the temperature of materials such as aluminum alloys which have low emissivity and require low heat treating temperatures.

In some instances, a modification of the usual high-speed radiation element appears useful. This modification, which has been used in some crystal growing applications, involves the use of a ⅛-in. sapphire rod in place of a lens. Radiant energy moves from the target through the length of the rod to the thermopile in the radiation head. The sapphire rod sights a very wide area of the crucible base, thus transmitting a signal corresponding to the average melt temperature.

Control Systems Are Better

A variety of novel control systems have been designed which use the electrical signal developed by thermocouple or radiation sensing elements to control the temperature. Each of these systems makes use of a potentiometer-type high-speed controller or recorder, or both.

Fig. 2 – Arrangement of Apparatus for Growing Crystals of Germanium for Transistors. Current proportioning control, magnetic amplifier, and saturable reactor help to achieve precise temperature control. Inset shows position of induction coil and quartz envelope which contains the crucible. Radiation element is focused on crucible base

The controller compares the measured temperature (as indicated by the radiation or thermocouple sensing element) with the preset temperature of the controller. Any difference in temperature is then used to activate power control devices. Special features of the controllers used in induction heating are: very rapid response (full-scale travel in 0.25 sec.) and rapid chart speed (up to 1 in. per sec.). Temperature correction is obtained by automatic regulation of the power supplied by the induction generator.

A large number of induction heating applications involve heating individual parts or assemblies to a given temperature before further processing. Quenching and hot forming are two familiar examples. In such applications, the primary requirements of the sensing device and control system are accurate indication of the temperature of the piece being heated, minimum overshoot of the preset temperature, and development of a signal that activates the operation following heating.

For such applications, a thermocouple or radiation sensing element and a two-position controller with an on-off contactor provide suitable control. Such an arrangement is shown schematically by Fig. 1. When a timer and suitable relays are added, temperature can be maintained about a preset value for desired periods of time. Refinements of this technique involve high-low contactor control instead of on-off control or the use of thyratron control rather than contactor control of the generator.

A radiation sensing element can also replace the thermocouple. Since the radiation head is focused on the opening between coil turns, no contact is required with the piece. Thus, this arrangement is suitable for control of heating in production operations.

Current Proportioning Control

Some induction heating operations require progressive heating or very closely maintained temperature for long periods of time. For example, this may be needed when steel bars are

hardened and tempered, or wire and strip are annealed. The growth of single crystals of germanium or silicon by very slow withdrawal of a seed crystal from a closely controlled melt is another good example.

For each application, the desired temperature must be as constant as possible. Consequently, there should be some means for response to minute temperature changes. Power regulation with proportioning control units is necessary in such instances. In particular, current proportioning control units in conjunction with magnetic amplifiers and saturable reactors are successful in such applications.

Figure 2 shows the general arrangement of the apparatus and control system for growing crystals of germanium. To control temperature precisely, this equipment employs a radiation device as the sensing element, a controller-recorder, a current proportioning control, a magnetic amplifier, and saturable reactors. Relationship of these components is indicated in Fig. 3.

Essentially, two control loops are in operation. In the primary loop, an error signal, which is proportional to the deviation of the measured melt temperature from a set point, is developed by the control slidewire in the recorder-controller. This signal is delivered to the high-speed current output controller. Here, the error is continuously analyzed to determine the corrective action necessary to restore the melt temperature to the set point. An output signal is generated in accordance with this analysis, and fed to the magnetic amplifier where it is changed to the level required to operate saturable core reactors. These adjust the power supply of the induction generator.

In the secondary loop, the primary measuring element, its associated recording equipment and the process itself are bypassed through the use of a pickup coil. This coil detects the current level in the induction heating coil and develops a proportional d-c. signal that is fed back directly to the controller. Through this circuit, the control compensates promptly for line voltage change and other spurious effects that upset the temperature in the crystal growing process. This arrangement maintains the temperature of the melt to within 0.5° C. (1° F.) of its crystallization temperature for long periods of time. If desired, the controller can be automatically programed.

The current proportioning control unit in Fig. 3 is an all-electronic unit in which output is related to input on a three-function basis. A proportional component varies directly with the size of the input signal to give proportional control. An integral component varies both with the magnitude of the input signal and its duration; together, they provide reset action. Furthermore, a derivative component varies with the rate of change of the input signal to supply rate action. To complete the process, these three actions are suitably combined to produce the desired control signal. Calibrated dials permit separate adjustment of each control function in accordance with the requirement of the process under control to provide optimum control response.

The saturable core reactors are connected in each phase of the primary side of the plate

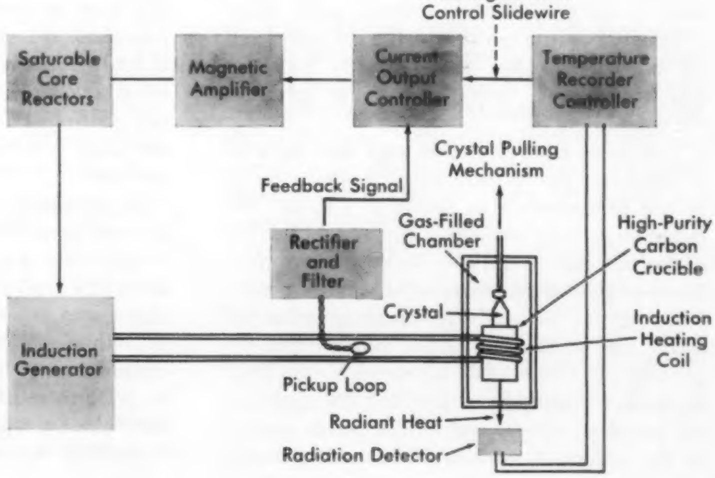


Fig. 3 – Block Diagram of Crystal Growing Arrangement Shown in Fig. 2. Interrelation and operation of the components are described in the text

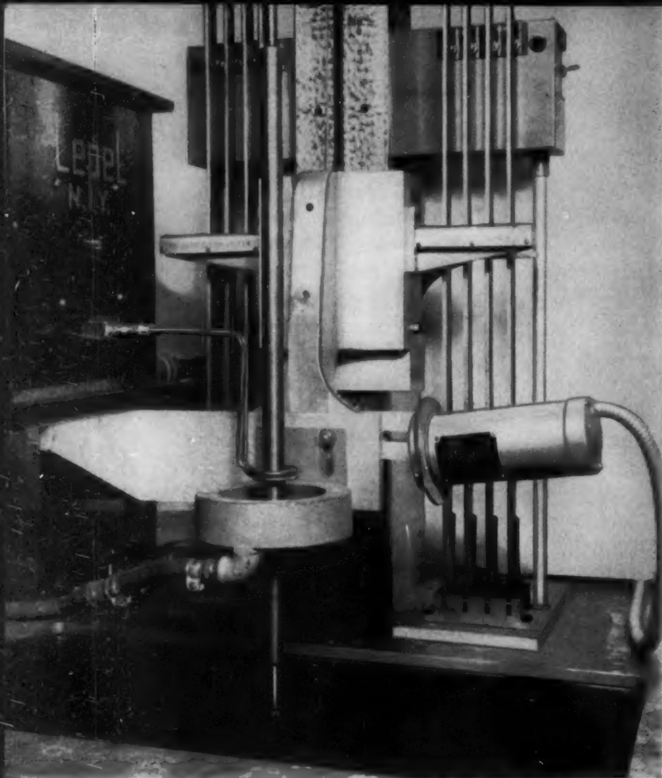


Fig. 4 – Arrangement for Progressive Heating Operation. Radiation element, proportioning control, and saturable reactor combine to maintain uniform temperature

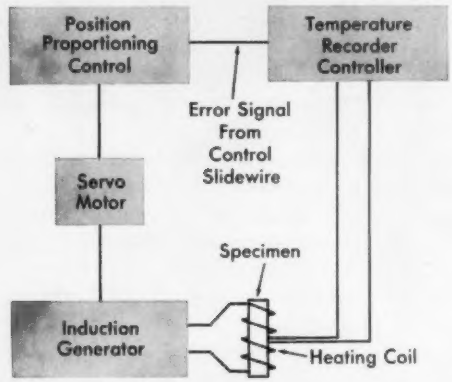


Fig. 5 – Diagram Illustrates Use of Position Proportioning Control and Servo Unit to Monitor Temperature in Accordance with Predetermined Program

transformer of the induction generator. They regulate the power delivered to the equipment by changes in their reactance. The d-c. control signal from the magnetic amplifier is fed to the reactors through a control winding, the ampere turns being such as to almost saturate the core at maximum current level. Under this condition, the reactance becomes small and the generator operates with maximum voltage supplied to the plate of the oscillator tube. Conversely, when the current to the control winding becomes smaller, the reactance increases and the voltage supplied to the plate is decreased.

This basic control system may also be used to monitor the temperature of parts being heated progressively as shown in Fig. 4. The radiation sensing element is focused on the bar at the exit end of the coil: its signal is proportional to the temperature. Corrections in temperature may be made by adjusting either the travel rate of the bar or the power from the generator. While such adjustments can often be made manually by controlling the speed on the progressive feed unit or the power control on the generator, automatic control is possible with the system described for crystal growing if the application warrants it.

Position Proportioning Control and Servo Unit

For some purposes, adequate temperature control can be achieved with a position proportioning control in conjunction with a servo unit which operates the power control on the induction generator.

In one instance, a thermocouple sensing element has been used, the individual wires of the couple being welded to the specimen between turns of the coil. The induction generator for this application is connected to the coil.

The block diagram in Fig. 5 illustrates how temperature control is achieved in this application. In operation, a deviation of the specimen temperature from set point changes the position of the controller slidewire. An error is continuously analyzed, and the corrective action necessary to restore the specimen temperature is applied as a result of proportioning, rate and reset action. The output from the proportioning control is fed into a converter and then amplified to drive a servo unit which regulates the power of the induction generator.

In conclusion, the past decade has seen many systems developed to measure and control the temperature of parts heated by high-frequency induction. Means are now available for the direct and close control of work temperature in either stationary or progressive heating operations. While automatic timers continue to perform satisfactorily in many applications, very close temperature control at a set point is available where the expense is justified.

Metallographic Exhibit

Metallographic Techniques for . . .

Age Hardening High-Temperature Alloys

*By R. P. MORENSKI and N. S. PITEA**

Nickel-base superalloys containing titanium are hardened by precipitation of Ni_3Ti, an intermetallic compound. Described in this paper is the metallography needed to reveal the changes in microstructure which occurred in one such alloy, and which are shown on the Data Sheet on p. 100-B. (M-20, N7a; Ni-b)

MANY SUPERALLOYS which are designed today for high-temperature applications are hardened by titanium. Control of their high-temperature properties has been advanced by phase study during aging. The present work is limited to the alloys in which the nickel-titanium binary system forms a base. Here, creep resistance is controlled by microstructure, just as it is in many other systems. The transformation of Ni_3Ti, the age hardening constituent, from the face-centered cubic form to the hexagonal close-packed form occurs inside the grains and at the boundaries. This reaction results in overaging. To observe these critical changes, proper metallographic specimen preparation is very important.

The specimens used for this study were taken from vacuum-melted, hot forged and rolled stock of a binary composition of 87.8% Ni, 12.2% Ti with less than 0.005% B. After solution treating in argon gas for 2 hr. at 2200° F., the samples were water quenched and isothermally aged at the following temperatures and times with resultant hardness values:

Aging		Diamond Pyramid Hardness,
1 hr.,	1600° F.	282
8	1600	282
50	1400	310
100	1400	310
100	1200	380
500	1200	380

First, the specimens were ground on a coarse emery belt (120 grit) to remove any oxide or adverse surface condition incurred during heat treatment. Grinding on successively finer grits (180 to 600) of dry silicon carbide paper followed, with each specimen being rotated 90° to the striations of the previous grinding. Thorough washing with soap and water between each grinding step was imperative. Following this, two more grinding operations were necessary to yield scratches fine enough to be easily "polished out" in the rough polishing operation. Grinding on a graphitized sheet of 600-grit silicon carbide paper was followed by grinding on a sheet of graphitized 600 paper coated with a solution of paraffin and kerosene. In the finish grinding, paraffin and kerosene were used to prevent particles of silicon carbide from becoming embedded in the surface.

Of the many rough polishing procedures investigated, two methods which gave comparable results were used. The first of these was to polish the specimens with a 10-micron diamond paste on a nylon-covered wheel rotating at 125 rpm. Alternatively, a silk lap was used on a rapidly rotating wheel with a slurry of alumina (Linde A). Both techniques left some very slight scratches.

Next, intermediate polishing was done with

*Research Laboratory, International Nickel Co., Bayonne, N.J. The metallography described herein was performed for a technical paper entitled "Phase Transformation in Nickel-Rich Nickel-Titanium-Aluminum Alloys", by R. F. Decker and J. R. Mihalisin of International Nickel Co. The authors wish to thank Dr. Decker and Dr. Mihalisin for permission to use their data.

a microcloth on a wheel which rotated very slowly. A slurry of alumina (Linde B) was used in this step. Final polishing was performed on a silk-velvet lap on a slowly rotating wheel with a thin suspension of alumina (Linde B).

The polishing cloths were boiled for about 2 hr. before use to remove all contaminants and abrasive particles, and alumina suspensions were made with distilled water.

Several etching methods were investigated. Most of the electrolytic etchants revealed a mediocre amount of detail in the microstructure, and pitted the specimen surfaces rather severely. Swabbing with glyceregia (30 parts glycerin, 20 parts concentrated HCl, and 10 parts concentrated HNO_3) did not pit the surface as readily as the electrolytic etchants, but objectionable relief appeared. Dip etching in a modified glyceregia solution (six parts glycerin, five parts HCl and one part (HNO_3) brought out the structures very well without the adverse pitting and relief. Though the dip etchant required a longer time to attack the surface, the time could be decreased considerably by heating the specimen to about 100° F. in hot water before etching. By decreasing the time required to etch the specimens, the risk of pitting and staining, usually encountered in long-time etching, was minimized. The same procedure was used for both the light and electron photomicrographs.

Light photomicrographs were taken with a Bausch and Lomb metallograph (Balphot model) at 100 × on Kodak contrast process orthochromatic film. Electron micrographs were made from negative parlodion replicas dry stripped from the samples. These replicas were metal shadowed, under vacuum, with germanium at an angle of 70° from the perpendicular. A Philips electron microscope (Model EM 100 A) was used to take the micrographs. Conditions: 100-kv. beam on Kodak lantern slide plates at a magnification of 5000 ×. The plates were then enlarged photographically to 10,000 × for the final prints.

[redacted]ght Metallurgy

A Crystal's Lament

I am a little crystal
In a polycrystal sea,
There are many other crystals
And they're pretty much like me.
I don't have much to do with most
Except quite distantly
But some of us get together
At the old grain bound-ary,
At the old grain bound-aree!

That's where the dislocations meet
When the tension gets too high
Warming their backs, against the stacks
Of amorphous nuclei.
Bawdy songs and ribald laughter
Fill interatomic space
As they chide a sessile companion
Who has been just put in his place.

Then over potential hills they leap
The cry is "Up and at 'em!"
To free a friend who is caught by his end
On an oversized solute atom;
Or with voices hushed and with mournful
shudders
They bemoan the fate of two lost lovers,
Beyond the help of resurrectors;
They embraced – having opposite Burger's
vectors.

At the old grain boundary–
That's where the dislocations go
When the tension gets too high;
On a summer's day I've seen it show
A million p.s.i.!
How can I stand it?
It baffles old Mott,
He thinks that I'm perfect
But I know that I'm not.

I've got my faults; in fact quite a few
I've got Frank-Read Sources;
And dislocations, edge and screw.
But when stresses race madly amid my cross
sections
And my lattice is twisting in several directions
What keeps me from yielding in plastic
deflections,
Even in spite of my own predilections?
It's not the same force that binds Isoldes to
Trist'ems –
It's the fact that I've got only four slip systems.

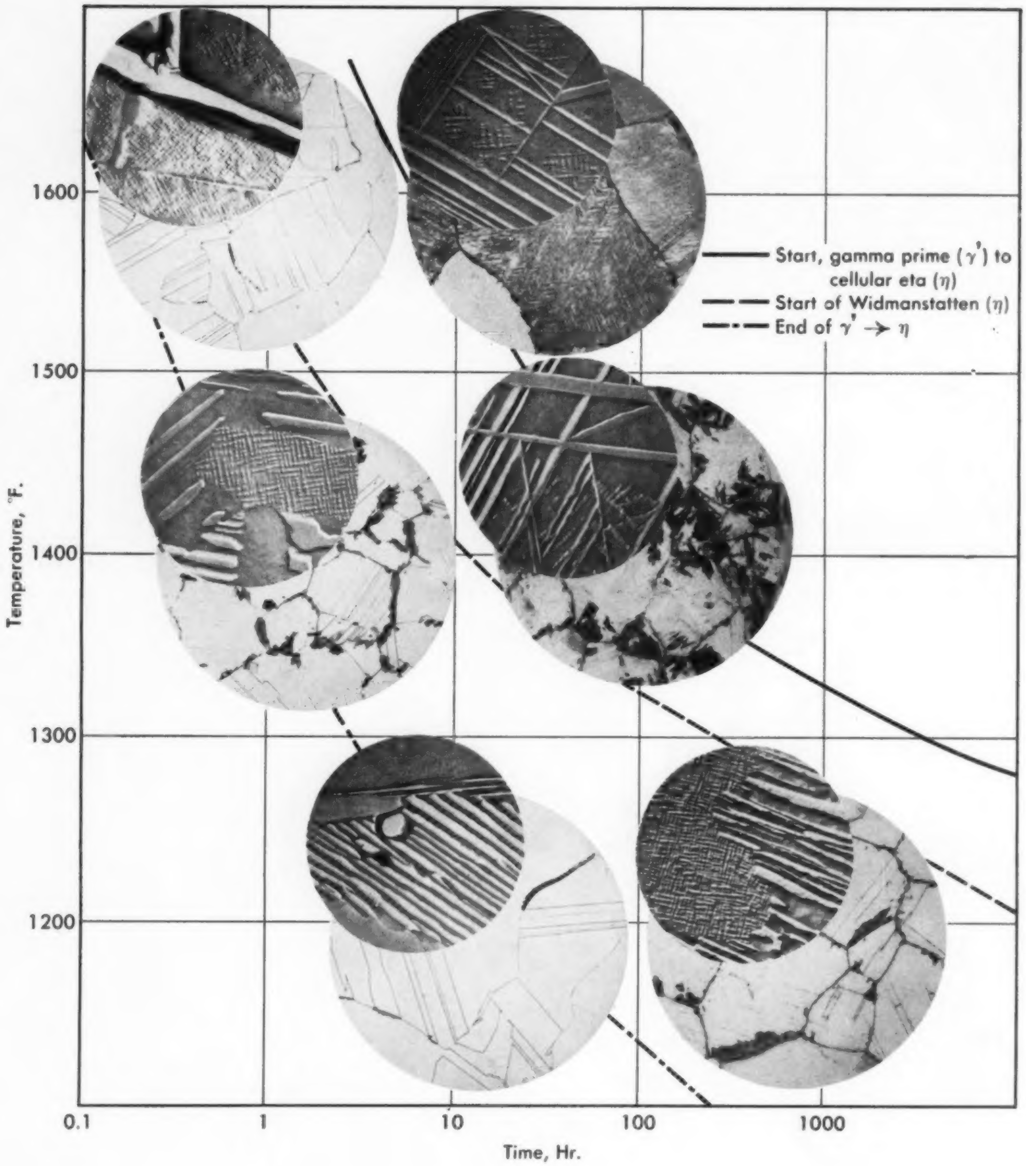
H. D. Block

Circle 873 on Page 48-A

Phase Transformations in a Nickel-Titanium Alloy

By R. P. MORENSKI and N. S. PITEA
International Nickel Co., Inc.

Prizewinner in 14th Annual A.S.M. Metallographic Exhibit, Chicago, November 1959



Creep resistance of high-temperature alloys is controlled by the microstructure. In many such alloys, the nickel-titanium binary system plays an important role. The alloy depicted here, which consists of 87.8% nickel and 12.2% titanium, represents that system. On the TTT-curve, optical and electron micrographs illustrate the transformation of Ni_3Ti, an intermetallic compound, from the face-centered cubic structure (cubic particles) to the hexagonal form (lamellar and Widmanstätten structure). This reaction occurs inside the grains and at the grain boundaries. The etchant is glyceregia, the optical micrographs are at 100 ×, and the electron micrographs are at 10,000 ×. For further details, see p. 99.

in this zone, stainless steels that remain ductile with high strength and stability

In the search for favorable strength-to-weight ratio, high temperature alloys have been developed with extreme strength up to 1000 F, but at the expense of ductility.

In AM 350 and AM 355, Allegheny Ludlum's precipitation hardening stainless steels, you have high hardness and stability from room temperature to 1000 F, plus almost twice the ductility!

These advantages are followed by easy formability using normal techniques. AM 350 and AM 355 can be brazed and welded as easily as the common stainless steels. They can be spun, formed and machined without special preparation.

AM 350 is available commercially in sheet, strip, foil, small bars and wire. AM 355, best suited for heavier sections, is available commercially in forgings, forging billets, plates, bars, wire, sheet and strip.

For further information, see your A-L sales engineer or write for the new technical booklet, "AM 350 and AM 355." **Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Penna.**

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A-L

EVERY FORM OF STAINLESS . . . EVERY HELP IN USING IT

Circle 874 on Page 48-A

Circle 875 on Page 48-A

Radio-Isotopes in Metallurgy

Reported by W. A. MUDGE*

The reporter suggests that radio-isotopes have a wide but as yet unexplored field in metallurgical laboratories and pilot plants. (A-general, 1-59, 14-63)

THE NEWLY FORMED Office of Isotope Development of the U. S. Atomic Energy Commission is holding a series of conferences throughout the United States wherein six or eight specialists in various branches of the field contribute discussions. The following notes were taken from a meeting at the Franklin Institute in Philadelphia, Jan. 19 and 20, 1960. Similar meetings are scheduled for San Francisco in February, New Haven in March, New York in April, and Dallas in May.

The topic, of course, is not new. Applications in research date back to the end of the last war. Innumerable articles appeared in the scientific, engineering and technical press. Several volumes have appeared, at least one of them of very imposing demensions.† However – and this was the underlying theme of the conference – only a fraction of the potentialities have been accomplished, and the remaining possibilities largely depend upon the imagination and enterprise of men in industry.

Another point was stressed: Their use is not at all hazardous when handled by men of adequate knowledge and in possession of safe equipment. All this is available. In retrospect it only appears natural that the first applications were in the life-sustaining sciences, medicine and agriculture – next in chemistry, and last in metallurgy. While the work horse of biological research, radio carbon, is often useful to metallurgical investigators, their more exacting requirements of elements of suitable half-life, energy, and facility of measurements have been complicated by a scarcity of trained operators and technicians. *Total* growth and expansion in all fields in a decade have been great with more than 1600 corporations licensed to use them. In fact, radio-isotopes have constituted the foremost peaceful use of atomic energy, despite the large public interest in nuclear reactors for power production. Nevertheless the metallurgist is disappointed that his field appears to have been neglected.

It was therefore not surprising to this reporter that the formal program of the conference emphasized accomplishments in the medical, chemical and petroleum fields. However, metallurgy was not omitted although opportunities to learn about and discuss applications in this field were better during the intermissions, the coffee-breaks and the luncheon periods than during the question and answer periods which followed the formal presentation of papers.

The use of radio-isotopes is safe and they are not difficult to control. C^{14}, P^{32}, S^{35}, Ca^{45}, Fe^{59}, Co^{60}, Cs^{137}, Ir^{192}, and many others offer more precise opportunities than the conventional quantitative analyses and need only ingenuity and determination to equal and perhaps even surpass the recent accomplishments in petroleum engineering.

Wear studies, β-thickness gages, measurement of ceramic and other nonferrous coatings on steel, liquid-level measurements, corrosion inside pipe lines and other containers, and diffusion in metals and alloys have been demonstrated and used. These results have inspired research efforts which have uncovered, partially if not completely, the necessary data and techniques for more exacting and profitable applications in laboratory, production line or final inspection. *(Continued on p. 169A)*

*Consulting Editor, *Metal Progress.*

†The U.S. Atomic Energy Commission List of Special Sources of Information on Isotopes (TID-4563) is a 50-page pamphlet.

Properties of Malleable Iron at Elevated Temperatures

By L. C. MARSHALL,
G. F. SOMMER
*and D. A. PEARSON**

Elevated-temperature properties of malleable irons point out their excellent load-carrying ability. Already in service at 1100° F., malleable iron parts will find greater application particularly where strength and resistance to creep are important. (Q27a, Q3m, 2-62; CI-s)

MANY COMBINATIONS OF PROPERTIES are available in the standard grades of ferritic and pearlitic malleable iron. In addition, other grades of malleable iron may be produced to obtain specific properties. Widely published room-temperature tensile properties of the standard grades, which are listed by the American Society for Testing Materials, provide useful design information for many applications. This report summarizes data on the behavior of malleable iron at elevated temperature.

The results of current research demonstrate the ability of malleable iron to sustain high loads for extended periods of time. Designers have employed ferritic and pearlitic malleable iron castings in applications where temperatures reach 1000° F. The parent "white iron" from which malleable iron is normally produced has been used in some of these installations.

Figure 1 illustrates cast chain links of pearlitic malleable iron which are used in conveying aluminum billets through a furnace at 900° F. Special attachment-type links are visible in each of the four strands of chain. These links are designed to support the billets in their trip through the furnace. In spite of the complex design, the attachments are cast directly without the need for machining.

The conveyer-type chain assembly shown in Fig. 2 is frequently employed in furnaces operating at temperatures as high as 1700° F. Attachments secured to the center link extend up into the furnace so that the chain itself generally operates between 1000 and 1100° F. Maximum temperatures of 1250 to 1300° F. have been recorded, however, in chains conveying steel sheet through a normalizing furnace. The center links, outside bars and washers of this type of chain are made of pearlitic malleable iron with special grades being furnished for some applications to give greater wear resistance. It is interesting to note that the rollers shown are made from unannealed malleable or "white iron" in which all the carbon is present in the combined form as iron

*Dr. Marshall, formerly director of research, Link-Belt Co., is now associate technical director, Microwave Power Laboratory, Varo Mfg. Co., Inc., Garland, Tex. Dr. Sommer is assistant chief engineer and Mr. Pearson is assistant research engineer, Link-Belt Co., Indianapolis, Ind.

Table I – Tensile Properties of A.S.T.M. Malleable Iron Castings
Ferritic Standard A 47-52, Pearlitic A 220-55 T

Grade	Tensile Strength*	Yield Strength*	Elongation in 2 In.*
Ferritic			
32510	50,000 psi.	32,500 psi.	10%
35018	53,000	35,000	18
Pearlitic			
45010	65,000	45,000	10
45007	68,000	45,000	7
48004	70,000	48,000	4
50007	75,000	50,000	7
53004	80,000	53,000	4
60003	80,000	60,000	3
80002	100,000	80,000	2

*Minimums.

Fig. 1 – Cast Chain Links of Pearlitic Malleable Iron Used Here in a Billet Furnace Operating at 900° F.

carbide. White iron can be alloyed with elements such as chromium for increased wear resistance.

The grate bar shown in Fig. 3 is another application of pearlitic malleable. Used in sintering machines, parts like these can operate at temperatures up to 1250° F.

Malleable iron has excellent machinability. Thus, parts can be machined with close dimensional tolerance and excellent surface finish. Pistons for diesel engines, an example of machined parts, provide excellent service at temperatures up to 750° F. Replacement of these pistons in trucks and buses may occur at 300,000 miles but many run over 1,000,000 miles. Some operators of road building equipment report that pistons give at least 6000 hr. service.

Table I shows the tensile properties for various standard A.S.T.M. grades of ferritic and pearlitic malleable iron. The composition of malleable irons generally falls within the range of 2.00 to 2.70% carbon, 0.80 to 1.30% silicon

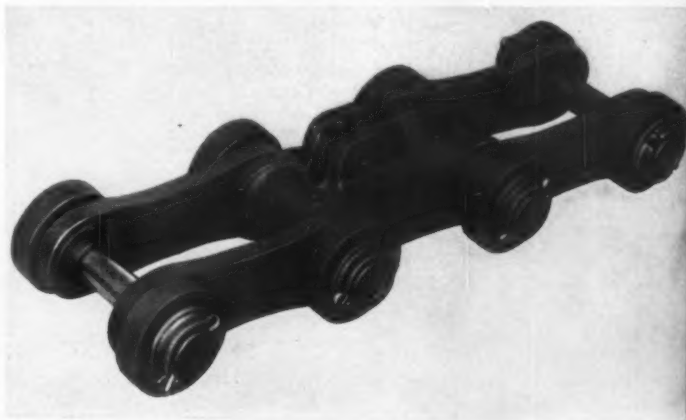
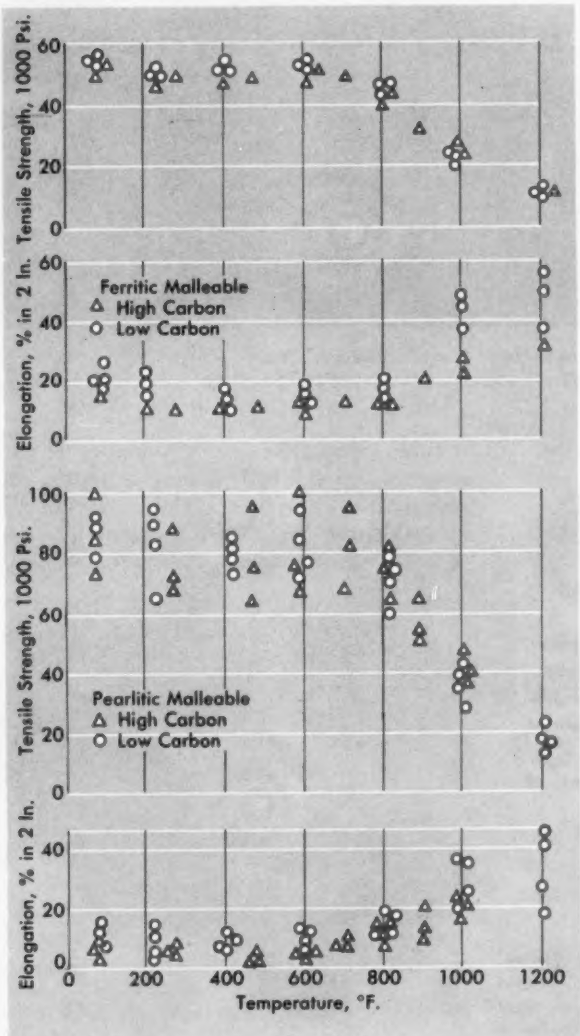


Fig. 2 – Chain Assembly Designed for Operation at 1100° F. Center links, outside bars, and washers are made of pearlitic malleable iron surface hardened for maximum wear resistance

Fig. 3 — Grate Bar Casting of Pearlitic Malleable Which Contains Manganese for Carbide Stabilization. Designed for use in sintering machines, the part, which can operate up to 1250° F., will last 18 months to several years depending primarily on sintering temperatures. This grade of pearlitic malleable finds other applications where shock and wear resistance are important

Fig. 4 — Effect of Temperature on Short-Time Tensile Properties of Ferritic Malleable Iron



and 0.30 to 0.90% manganese. Other elements are also present in controlled amounts depending on the producing foundry and the mechanical properties desired. Malleable iron solidifies in the "white" condition with all of the carbon in the form of iron carbide. Subsequent heat treating transforms the structure to a ferritic or pearlitic matrix in which are dispersed graphite or "temper-carbon" nodules. Ferritic and pearlitic malleable irons take their name from the type of matrix which appears in the microstructure. It is also possible to produce malleable iron with a martensitic matrix. Sometimes this heat treatment is applied locally by means of induction or flame hardening. Frequently the entire part is hardened.

High-Temperature Tensile Properties

Typical short-time tensile properties for various grades of malleable iron are contained in reports by several investigators. Some of these are shown in Fig. 4 and 5. Data presented represent a summary of work conducted at Battelle Memorial Institute, sponsored by the War Metallurgy Div. of the National Defense Research Commission, and by the University of Wisconsin, sponsored by the Malleable Founders' Society.

It can be seen that tensile strength changes very little until the temperature is raised to about 700° F. Beyond 700° F. there is a rapid decrease in strength in both standard ferritic and pearlitic malleable irons. Elongation drops off immediately above room temperature, reaches a mini-

Fig. 5 — Effect of Temperature on Short-Time Properties of Pearlitic Malleable Iron

mum of 400 to 600° F. for both ferritic and pearlitic and then increases to as high as 60% at 1200° F. for standard ferritic malleable irons. Yield strength and reduction of area, not shown on the curves, follow the same pattern as tensile strength and elongation, respectively.

Stress-Rupture Properties

The stress-rupture results obtained during a research program sponsored by the Malleable Founders' Society are summarized in Fig. 6 and 7.*

Figure 6, a log-log plot, gives stress-rupture data for low-carbon ferritic malleable irons at 800° F., high-carbon ferritic iron at 800° F., and both high and low-carbon ferritic malleable irons combined at 1000 and 1200° F.

The solid lines represent equations determined from the available data by the method of least squares. The lower dashed curves in each band define time and load for 95% survivors, and the upper dashed curves are the boundaries for the 5% survivors. The dashed extrapolations of the least square line are from calculations to determine the 1, 10,000 and 100,000-hr. intercepts.

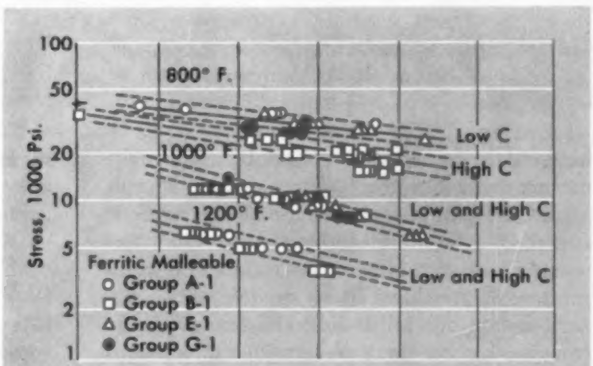
The data obtained thus far with the standard malleable irons indicate a general high level of rupture stress which is equal or superior to ferritic cast materials for which data are available, particularly at 800° F. There is no evidence in any of the experimental results of abrupt changes in behavior or structure during the test periods, which extend from approximately 1 to over 2000 hr. All the stress-rupture data thus far exhibit a good linear fit on the log-log plots, with no breaks in slope of the curves, as might be expected if fundamental changes were taking place. Metallographic examination confirms the fact that there are no abrupt changes in microstructure. For these reasons, malleable iron is useful in special applications such as ovens, driers, furnaces, and high-temperature fittings, both structural and plumbing.

In Fig. 6, data for both low and high-carbon ferritic malleable irons appear to group closely at 1000 and at 1200° F. as well. The methods of analysis employed give no certain indication of a significant difference in the behavior of the materials. More data are desirable at the longer times, particularly at 1200° F. With this caution in mind, there appears ample justification for regarding both materials as identical in stress-rupture properties at 1000 and 1200° F.

At 800° F., however, a distinct separation favoring the low-carbon malleable iron appears

*All stress-rupture tests were conducted in the School of Metallurgical Engineering, Purdue University, under the supervision of the Steering Committee of the Research and Technical Council, Malleable Founders' Society. The authors give special acknowledgment to R. Schuhmann, Jr., Head of the School of Metallurgical Engineering, for making facilities and student help available to the Society.

Fig. 6 – Stress-Rupture Plot for Ferritic Malleable Iron. Solid lines in each band are curves determined by method of least squares from existing data. Lower dashed line in each band defines time and load for 95% survivors; upper dashed line is boundary for 5% survivors



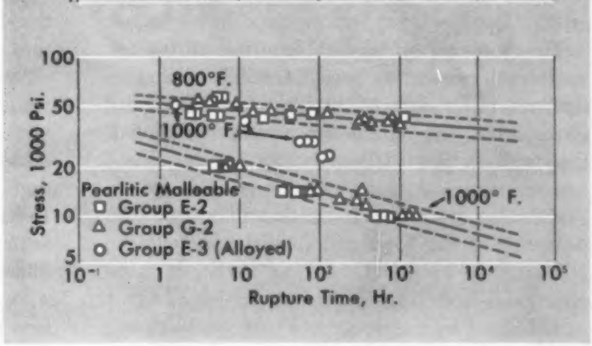


Fig. 7 – Stress-Rupture Plot for Pearlitic Malleable Iron. See Fig. 6 for explanation of solid and dashed lines. Data from tests on alloyed grade demonstrate potential improvement obtained by additions to the basic pearlitic composition

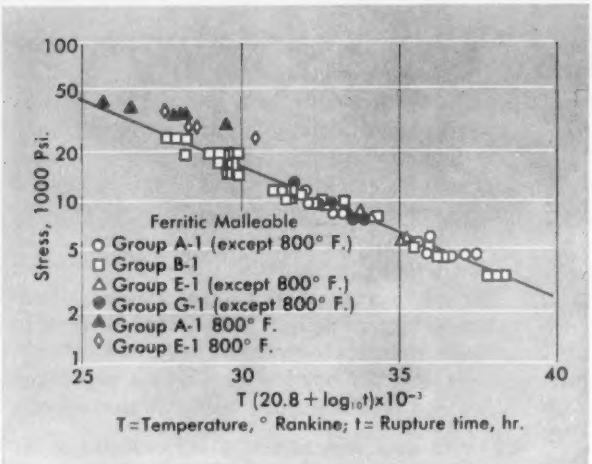


Fig. 8 – Larson-Miller Plot for Ferritic Malleable Iron. Some points have been staggered to accommodate all the data

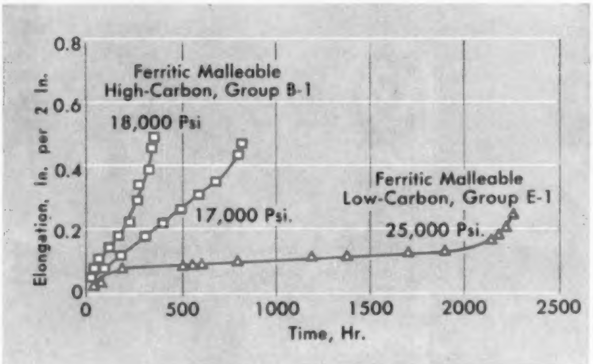


Fig. 9 – Creep Curves for Two Groups of Ferritic Malleable Iron at 800° F.

in the data for the two materials. The high-carbon malleable iron has considerably shorter life at comparable stresses for all test periods covered. Allowable working stresses for this material must, therefore, be reduced in comparison to the low-carbon grades. Still, the high-carbon malleable iron has considerable promise for use in load-carrying applications at 800° F.

The low-carbon malleable iron at 800° F. appears, however, to be outstanding in characteristics. The slope of the least squares log-log curve fitting the data is not as steep as that of the high-carbon malleable iron at the same temperature. A few points, not shown in Fig. 6, also give some indication that at 860° F. behavior of the high and low-carbon material may still be identical. In any event, tests on specimens from three producers, which all agree as indicated by the curve in Fig. 6, yield strong evidence that low-carbon malleable iron at 800° F., and for an undetermined range below, may be an entirely different material from high-carbon ferritic malleable in mechanical and physical characteristics. These experiments give no direct evidence concerning the nature of these differences. Further work is needed and will be carried out. It is possible that electron micrographs employing new carbon replica techniques, with improvement in resolution limit to 20 Angstroms or better, may yield information of value concerning possible changes in the microstructure over these ranges of experimental parameter.

Figure 7 presents the data obtained thus far from two groups of standard low-carbon pearlitic malleable irons, and one group of alloyed samples. Specimens are from two different suppliers and were produced by the method of arrested graphitization. The two standard groups meet the tensile requirements of the first five grades of pearlitic malleable iron of A. S. T. M. Specification A 220-55 T. One, G-2, falls very close to the requirements of grade 60003 and is borderline only in yield strength. At 800 and 1000° F., rupture stress of the E-2 and G-2 pearlitic specimens is superior to that of the ferritic malleable irons at the same temperature. However, the least squares curve through these points indicates that the minimum rupture stress of pearlitic grades is superior and parallel in trend to the low-carbon ferritic material at the same temperature (see Fig. 6).

The values obtained for the unalloyed pearlitic malleable irons compare very favorably with those irons to which molybdenum has been added. Pearlitic irons in this study appear equal to alloyed high-carbon pearlitic malleable irons containing as much as 0.5% molybdenum which is added to stabilize the carbide phase. They also appear to be superior to other unalloyed pearlitic cast irons and equal or superior to most alloyed cast irons.

Alloyed low-carbon pearlitic malleable iron (group E-3, Fig. 7) shows greatly improved strength at both 800 and 1000° F. compared with the unalloyed groups. By approximately doubling the load-carrying ability of pearlitic malleable iron at high temperatures, alloying shows promise of expanding the applications of malleable irons. These test results demonstrate the improvement currently possible by alloying and do not necessarily represent the limit of such improvement.

Larson-Miller Plots

Stress-rupture data are sometimes presented in the form of Larson-Miller plots* which relate stress, temperature and time, and permit an estimate of rupture stress at temperatures other than those at which the material was tested. Figure 8 shows a Larson-Miller plot for ferritic malleable iron of log rupture stress against $[T(20.8 + \log_{10}t) \times 10^{-3}]$, where T = absolute temperature (° Rankine) and t = rupture time (hr.). Calculated intercepts from the curve for 1, 1000, 10,000 and 100,000 hr. at 800, 1000 and 1200° F. agree with those obtained from log rupture stress-log time curves in Fig. 6.

Time-Elongation Measurements

Time-elongation curves for several groups of ferritic and pearlitic malleable irons exhibit the three stages of typical creep curves. The normally ductile behavior of both pearlitic and ferritic malleable iron at all times and temperatures investigated are typified in curves of this kind. No significant change in either elongation or reduction in area with time has been observed. Variations with temperature occur as described (Fig. 4 and 5) for short-time tension tests at elevated temperatures.

The curves in Fig. 9 illustrate changes which occur in the shape of the time-elongation curve at different loads for two groups of ferritic specimens. Values obtained for the minimum creep rate (linear or second-stage portion) vary from less than 0.0017% per hr. for long rupture times to 4% per hr. at the highest stress levels and short times for the various conditions included in this study. It should be noted in Fig. 9 that the long-time test at 25,000 psi. is from a different group than the other two curves shown. These two groups showed different elongation values at 800° F. so that it is not to be concluded that any loss of ductility occurred in the longer time tests.

Extension measurements actually represent the sum of elongation due to creep as well as that which might result from growth of the specimen such as would be caused by oxidation. Examination of microstructures and measurements on test specimens indicate that growth is not significant. Since malleable iron is highly ductile, its rapid elongation during the third stage of creep is assumed to be caused by the increase in stress resulting from reduction in area. For some materials of rather low ductility the third-stage portion can be obtained as the result of structural changes. This does not appear to be true with either pearlitic or ferritic malleable iron.

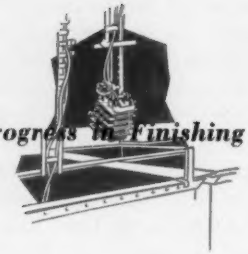
Metallography

Extensive metallographic examination has been carried out on all specimens in the stress-rupture research program. Specimens were sectioned both longitudinally and transversely in the area of fracture. Micrographs show that in typical low-carbon ferritic malleable specimens exposed at 800° F. failure is through the grains. At 1000 and 1200° F. failures occur in the grain boundaries. These metallographic studies also indicate that no observable graphitization has occurred in any of the tests carried out to date.

Summary

Even with rather limited knowledge of its high-temperature properties, malleable iron has found successful application up to 1100° F. Intermittent maximum temperatures of 1250 to 1300° F. have been recorded in some installations. With knowledge gained in recent years from short-time tensile tests and from current research on the stress-rupture properties of various grades of ferritic and pearlitic malleable iron, designers will be able to make even greater use of this versatile material. Improved properties resulting from alloying appear particularly promising. As greater knowledge of the elevated-temperature properties of malleable iron becomes available, engineers concerned with establishing codes and specifications will undoubtedly be able to utilize this material to a greater extent.

*A more thorough discussion of Larson-Miller plots can be found in "A Time-Temperature Relationship for Rupture and Creep Stresses", by F. R. Larson and J. Miller, A.S.M.E. *Transactions,* Vol. 74, 1952, p. 765, and "Stress-Rupture Properties of Malleable Iron at Elevated Temperatures", by L. C. Marshall and G. F. Sommer, A.S.T.M. *Proceedings,* Vol. 58, 1958, p. 733.



Flat Polished Sheet for Auto Bumpers

STAFF REPORT

Chevrolet holds down production costs on bumpers by flat polishing sheet stock before forming. Fed through one of three lines, each made up of some 15 abrasive-belt polishing units, sheets come out with a smooth finish, phosphate coated and lubricated ready for forming. (L10b, L14b; ST)

AUTO MAKERS HAVE SOME unique production problems and have come up with interesting techniques which improve not only producibility but quality as well. One example is in the manufacture of bumpers where the problem is to make a lot of them fast without sacrificing corrosion resistance or appearance.

Key step in the production of plated auto and truck bumpers is the surface preparation of the sheet stock from which they are made. To do this job economically and at high production rates, auto makers have turned in recent years to abrasive-belt polishing. For example, Chevrolet's Spring and Bumper Plant in Livonia, Mich., has three lines of abrasive belts, each made up of 14 to 15 Murray-Way Micro-Polish units (Fig. 1). Basically, the sheet stock – fine grained S.A.E. 950 grade steel – is fed automatically through one of the lines, progressing from coarse to fine-grit abrasive belts. Sheets come out at the end of the line with the polished face coated with a lubricant ready for press forming.

Coming out of storage, sheets are first put through a spray pickle machine (Fig. 2). Here they are washed in hot water, spray pickled in a 10% sulphuric acid solution, then sprayed with a sodium carbonate solution, rinsed and dried.

From here the sheets, which are 18 to 36 in. wide and up to 0.150 in. thick, are fed into one of the polishing lines through a roller leveler. Grit size of the abrasive is reduced in steps:

Unit	Grit Size*	Unit	Grit Size*
1	80 (new)	8	100 (used)
2	80 (new)	9	100 (used twice)
3	80 (new)	10	100 (used twice)
4	80 (used)	11	180 (new)
5	100 (new)	12	220 (new)
6	100 (new)	13	180 (used)
7	100 (used)	14	220 (used)

*First ten units employ alumina abrasive bonded to X-weight cloth with resin-over-resin bond. Units 11 through 14 use resin-over-glue bond.

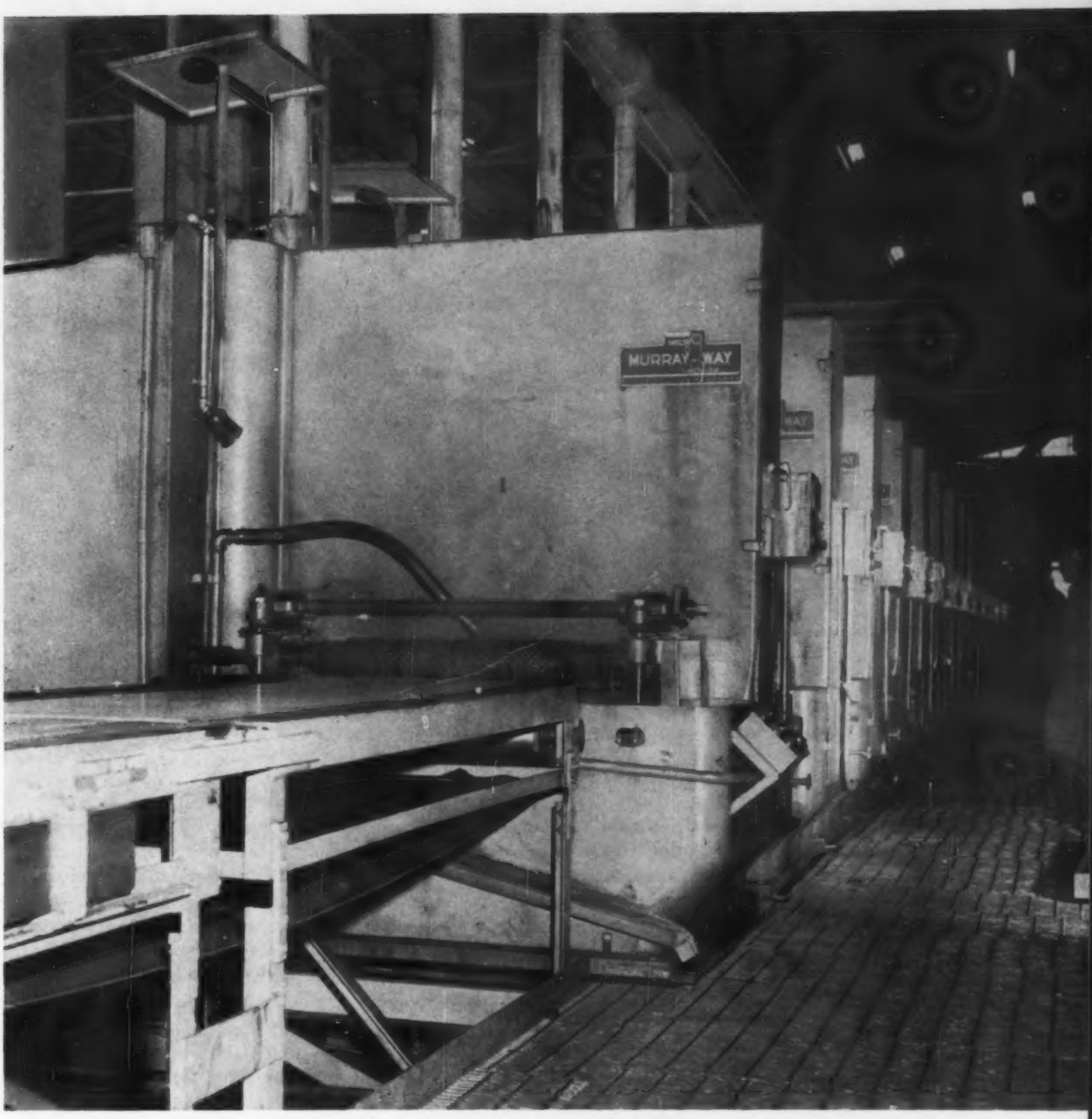


Fig. 1 — One of Three Flat Polishing Lines at Chevrolet's Spring and Bumper Plant. Pickled sheets are fed automatically through 14 to 15 polishing units which finish one face to about 6 to 8 micro-in.

Used belts are fed back into polishing heads farther down the line.

Although polishing can be either wet or dry, Chevrolet prefers the wet technique. Chevrolet says that wet polishing gives a better finish and longer belt life, and that it is just as economical in the long run as a dry operation. A mineral seal oil (SSU 45 to 50) serves as the lubricant. When contaminated with abrasive and metal particles, it is filtered and circulated back to

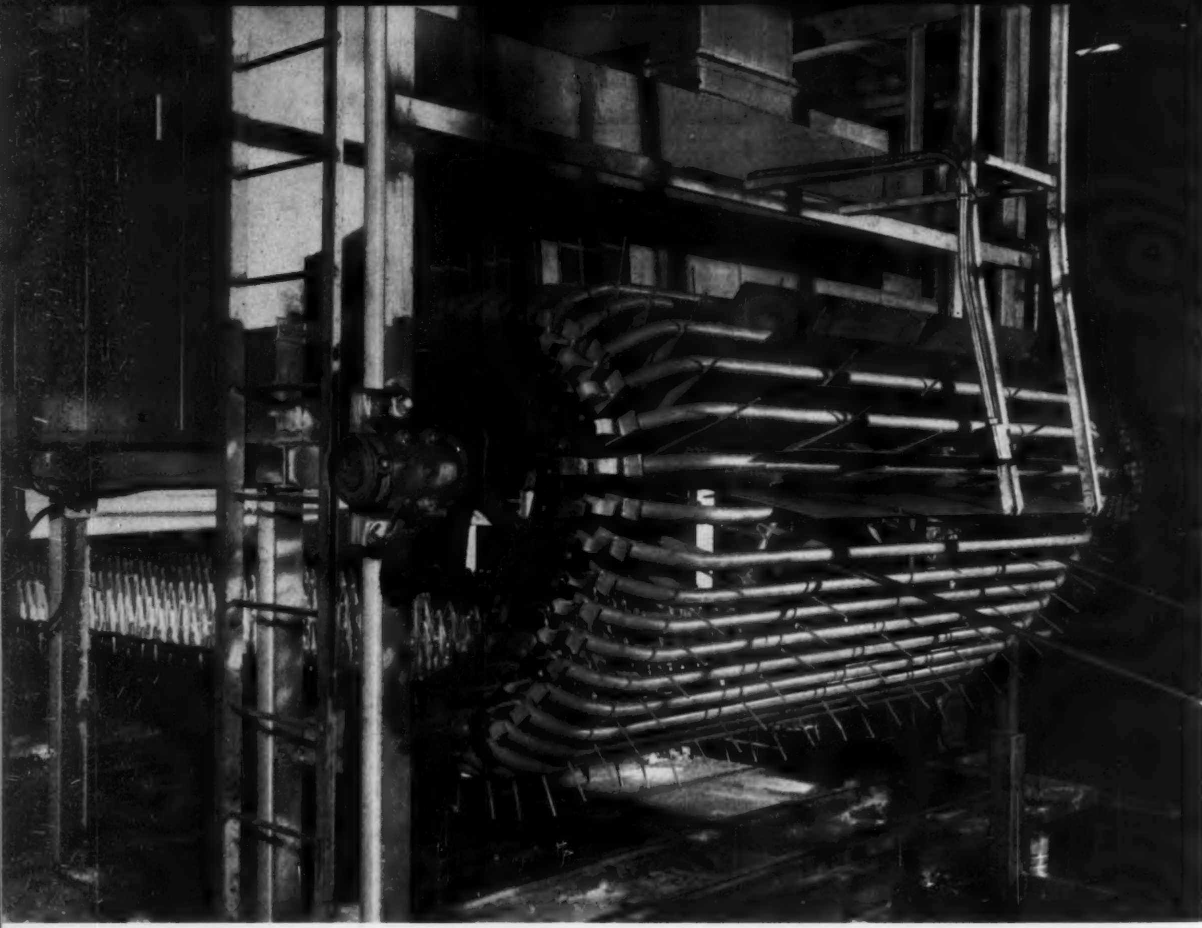


Fig. 2 – Discharge End of Spray Pickle Machine. Sheets go through machine racked vertically, are washed, spray pickled, neutralized, rinsed and dried. Next step is flat polishing operation

the polishing machines. The oil presents a possible fire hazard, but automatic CO_2 fire protection is provided throughout the finishing lines and no smoking is allowed in the area.

Alumina Abrasive Used

The belts are X-weight cloth flexed 90°. Alumina abrasive is bonded to the belt by resin over resin, a tough bond for initial roughing passes, and resin over glue for the finish passes where more belt and abrasive flexibility is desired. Alumina grit is used throughout for roughing and finishing to give a uniform scratch pattern. Use of alumina and silicon carbide would leave two types of scratch lines in the finished surface. Water-based lubricants have been considered, but the 30% increase in price for waterproof belts and the short belt life tend to discourage their use.

Aim of the polishing operation is a 6 to 8-micro-in. finish, but engineers at Chevrolet say that this is only a vague goal. For one thing, a profilometer does not measure gross defects or large scratches in finished sheet stock. Also, the surface finish may be ideal according to profilometer measurements but it has been found that "whiskers" of roughened metal, which do not affect readings, have a pronounced influence on the corrosion resistance of the plate. But Chevrolet keeps a close watch on surface finish with an eye for trends toward roughness which may indicate trouble in the polishing lines.

Only 0.00175 to 0.002 in. of sheet surface is removed, so the sheet steel must be free of deep-running defects. Sheet is sometimes put through the polishing lines again if defects are not removed the first time.

Phosphate Coating Protects Surface

After the stock travels through the last polishing unit, it passes through an alkaline cleaning tank, is rinsed in hot water, and coated with a zinc phosphate (about 175 to 200 mg. per sq.ft.) and a commercial drawing lubricant. When dry, the lubricant protects the polished sheet

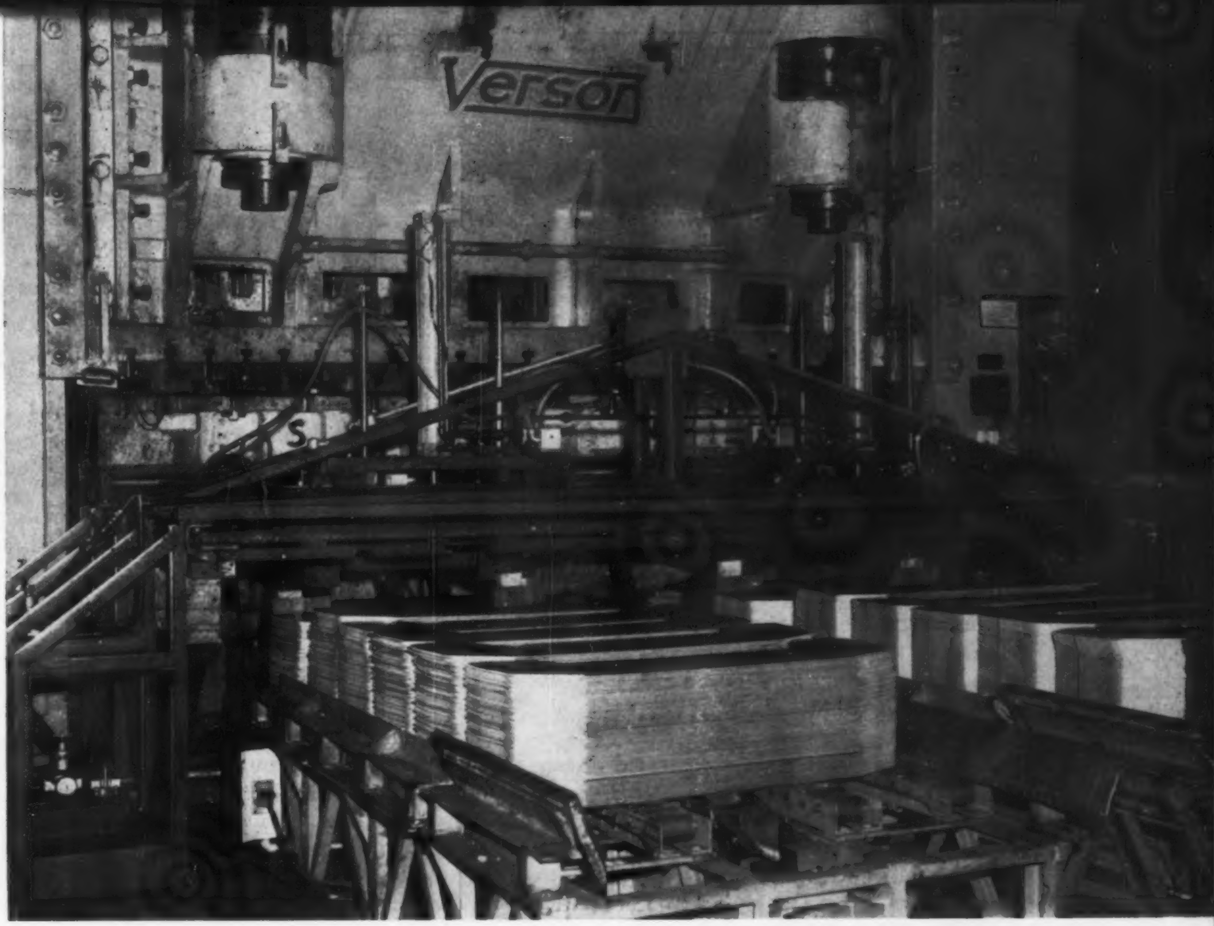


Fig. 3 — Press for Forming Center Section of Bumper. Stacked sheets have been belt polished, and coated with phosphate and a lubricant which protects surface during forming

quite well during the bumper forming operations (Fig. 3).

Bumpers on this year's Chevrolet will be electroplated with duplex nickel under conventional chromium. A layer of semibright nickel about 0.0005 in. thick is plated directly on the steel. This under layer is covered with a deposit of bright nickel of the same thickness, then plated with chromium.

Most bumper parts, such as the wing section shown in Fig. 4, do not need buffing but those which have rough or dull spots are picked off the monorail hangers and bypassed to the buffing line. Plating parts with duplex nickel is itself a quality control measure for the polishing lines because duplex nickel seems to accentuate any surface flaws resulting from poor sheet surface preparation.

Fig. 4 — Wing Section of an Automobile Bumper Which Has Been Nickel Plated. Duplex nickel, now used by Chevrolet, accentuates surface flaws in base metal and thus permits good control check on flat polishing step

Better Plate for Zinc Parts

STAFF REPORT

Developments in electroplating of decorative parts may give zinc die castings a more secure footing in the auto industry. L17; Zn, 5-61, *Cr*)

PROGRESS IS BEING MADE in improving corrosion protection afforded by bright plated coatings on zinc die castings. Developments discussed at a recent symposium in Detroit sponsored by the American Zinc Institute indicate that, as a result of concentrated efforts, methods for plating more durable coatings are rapidly coming to the front.

It was just a few years ago that the awakening came when auto makers expressed discontent over the performance of plated zinc die castings and began to turn their attention to aluminum. Certainly the increased use of de-icing salts on highways in recent years has been a more severe test for exposed decorative parts but this is not the whole story.

Duplex Nickel

One of the fairly recent plating techniques which has won acceptance is duplex nickel – a deposit of bright nickel over a semibright plate.

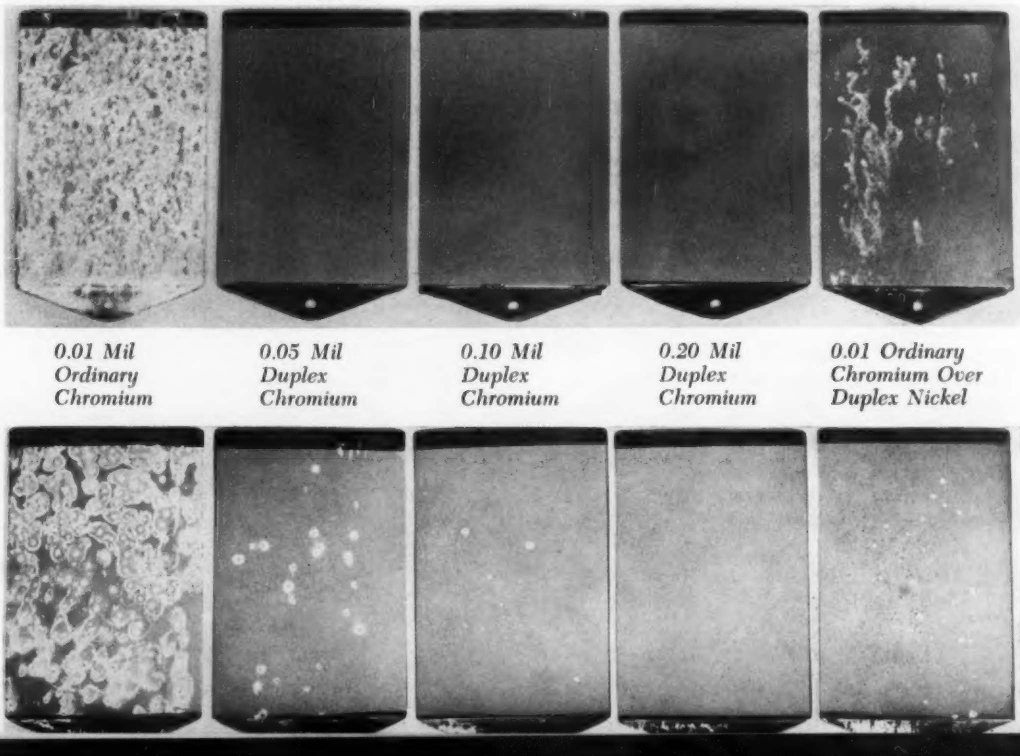
In tracing the history of this development, M. M. Beckwith, Harshaw Chemical Co., pointed out that the original intent of the double coating was to reduce or eliminate buffing before depositing the outer layer of chromium. Tests later showed that the process provided better corrosion resistance than did a single coating of bright nickel under chromium.

Duplex nickel, for example, slows the damaging effect of pits by laterally deflecting pit growth at the interface of the two nickel coatings rather than permitting direct penetration to the basis metal. The difference in structure of the two nickel layers does not seem to answer the question of why they give better corrosion resistance, according to Mr. Beckwith,

Fig. 1 – Effect of CASS and Corrodkote Tests on Zinc Die-Cast Panels Plated With Various Chromium Deposits on Single and Duplex Nickel Layers. Basis coating all panels: 0.3 mil copper, 1.0 mil nickel. (Courtesy Metal & Thermit Corp.)

CASS Test (272 Hr.)

Corrodkote Test (6 Cycles)



but further improvement is afforded by depositing sulphur-free, semibright nickel under the bright layer. Tests have shown that columnar semibright deposits beneath laminar bright nickel do not always give best protection.

Chromium Plating Developments

Other recent processes for plating zinc die castings were reported by Henry Mahlstedt, Metal and Thermit Corp., who described the characteristics of bright crack-free and duplex chromium deposits. Chromium has been thought useful only in protecting bright work from tarnish, but it is now recognized that chromium also plays an important part in corrosion resistance.

Bright crack-free chromium was commercially introduced early in 1957. Numerous tests by several investigators have demonstrated that when plated over copper (0.6 mil) and bright nickel (0.7 mil), for example, bright crack-free chromium, 0.07 mil thick, is superior to 0.010 mil of regular chromium in protecting zinc die castings from corrosion.

According to Mr. Mahlstedt, the quality of the underlying deposits and the surface cleanliness determine the protection afforded by thick chromium. Thus, if the nickel on which the chromium is plated contains pores or is not clean, blisters will form during corrosion tests which are larger (but fewer in number) than those which develop on test panels covered with chromium of ordinary thickness.

This problem led to the development of the duplex chromium technique which basically specifies that a second layer of chromium be applied over the crack-free variety. There have been numerous tests which demonstrate that duplex chromium provides even better resistance to corrosion than the bright crack-free type. For example, in one investigation several zinc panels were plated with 0.75 mil of copper and 0.75 mil of bright nickel. Over this was deposited – on separate panels – ordinary chromium (0.010 mil), 0.050 mil of duplex chromium, and 0.10 and 0.20 mil of duplex chromium, respectively. Results of CASS tests indicate that the panel with ordinary chromium dropped in A.S.T.M. rating from 10 to 4 after 36 hr. The other panels showed no evidence of corrosion. Ratings of those panels plated with duplex chromium did not drop until much later. For example, the duplex coating 0.05 mil thick decreased in rating to 6 after 136 hr. exposure to the CASS* test. Basis metal corrosion did not show up in the plate covered with 0.10 mil of chromium until 180 hr. of test. (It was assigned an A.S.T.M. rating of 6 after 460 hr.) After 480 hr. of exposure, the panel with 0.20 mil of duplex chromium still had a rating of 9.

Test panels have also been made which compare ordinary chromium, various thicknesses of duplex chromium, and duplex nickel. Results after CASS and Corrodkote† tests (Fig. 1) show the duplex chromium to be superior. The heaviest coating (0.20 mil) appeared least affected by the tests. Plating duplex chromium over duplex nickel also looks promising.

Chromium Over Duplex Nickel

Recent work at Doehler-Jarvis Div., National Lead Co., was reported by M. R. Caldwell. Principal aim of this investigation has been to determine the effect of various chromium deposits over duplex nickel. Results of electrographic printing, Corrodkote and CASS tests were used to evaluate the coatings. Baths which were investigated and plating conditions are given in Table I. Base for the chro-

*Corrosion test in which specimens are exposed to a mist containing about 5% NaCl, 95% distilled water, 1 g. per gal. $CuCl_2 \cdot 2H_2O$, and enough acetic acid (glacial) to bring the pH of the solution to 3.0 to 3.2. Test is carried out at about 120° F., usually in cycles of 16 hr.

†In this accelerated corrosion test, specimens are coated with a highly corrosive paste then exposed to high humidity for about 16 to 20 hr. Recommended paste composition is 0.035 g. $Cu(NO_3)_2 \cdot 3H_2O$, 0.165 g. $FeCl_3 \cdot 6H_2O$, 1.0 g. NH_4Cl, 50 ml. distilled water, 30 g. Kaolin.

Table I – Chromium Plating Baths and Plating Conditions*

Bath Designation	Anion	CrO_3:SO_4 Ratio	Temperature	Current Density	CrO_3
Sulphate type	SO_4	100:1	110° F.	195 amp. per sq.ft.	32 oz. per gal.
Hi CRT†	SO_4	150:1	130	230	45
Fluoride type A	Fl+SO_4	—	120	260	49
Fluoride type B	Fl+SO_4	—	120	195	26

*Baths were used to study effect of various chromium deposits on corrosion resistance of zinc die-cast panels plated with duplex nickel over copper. All panels were plated with 0.4 mil copper, 0.8 mil duplex nickel, then chromium from the different baths. Table courtesy M. R. Caldwell and L. B. Sperry, Doehler-Jarvis Div., National Lead Co.

†High-concentration, high-ratio, high-temperature bath.

mium plate was 0.8 mil duplex nickel over 0.4 mil copper.

Mr. Caldwell reported good performance of both single-layer (0.01 mil thick) and duplex chromium (0.03 mil thick) plated from the sulphate-type bath and of the heavy (0.05 mil) chromium plated from the fluoride type A bath.

Surface pitting in the 0.01-mil chromium showed up during the CASS test but not during two 20-hr. cycles in the Corrodkote test. The same tests resulted in surface pitting in the 0.03-mil duplex chromium panels; cracks were induced when the test plates were baked. Only cracking developed in the thick (0.05 mil) chromium plate from the fluoride bath.

Depending on what one considers the criterion for best performance, the choice, according to Mr. Caldwell, seems to be between cracking and pitting. His conclusions are that the 0.01-mil deposit has an obvious economic advantage and, over duplex nickel, it appears for the time being as good as any other form of chromium. More data will be available when panels which are exposed on a Detroit roof are ready for evaluation.

Comparison of Test Procedures

Differences in test results reported by advocates of one plating technique or another clearly demonstrate that evaluation of the effects of accelerated tests and their correlation with service performance is open to question. This point was emphasized by R. B. Saltonstall, Udylite Corp., who discussed his company's work in comparing results from the two accepted tests, Corrodkote and CASS, with those obtained during static exposure of plated panels and during exposure while mounted on automobiles in several cities.

The survey shows that on zinc die castings thicker chromium coatings (plates 0.03 and 0.01 mil thick were checked) stand up better than deposits of conventional thickness (0.01 mil) in the Corrodkote and CASS tests. Duplex nickel performed well, too, but its superiority to single layers of bright nickel in the accelerated tests was not confirmed on the panels mounted on automobiles, at least not during one winter's exposure. The panels will be out again this winter, mounted as before in groups of four, on the front of automobiles. Mr. Saltonstall recommends that the practice of accepting the results of accelerated tests without adequate correlation to actual performance in service "be discouraged to the greatest extent possible".

Since 1957, Battelle Memorial Institute has been working closely with the problem of corrosion of zinc die castings. The program, described by C. L. Faust, is sponsored by the American Zinc Institute. Here too, studies of panels subjected to the accelerated corrosion tests and to static exposure demonstrate the value of thick chromium (0.08 mil) in a bright crack-free form for improving the corrosion resistance of zinc die castings, more so than increasing the thickness of underlying layers of copper and nickel. Good results were also reported for duplex nickel if the semibright layer is deposited in columnar form. Again, chromium thicker than 0.01 mil gave pronounced improvement in corrosion resistance.

One phase of the work at Battelle dealt specifically with those plating variables which would affect the quality of chromium deposits. The results of this work, reported by W. H. Safranek, are based on corrosion tests and electrographic printing of zinc die-cast panels plated with 0.4 mil copper and 0.8 mil bright nickel before chromium plating. Best plating conditions for depositing thick crack-free chromium are as follows*:

Chromic acid	45 to 47 oz. per gal.
Sulphuric acid	0.29 to 0.30 oz. per gal.
Chromic-to-sulphuric ratio	150:1 to 160:1
Trivalent chromium	0.5 g. per liter min.
Temperature	130 ± 2° F.
Cathode current density	
Best for bright plate	300 to 350 amp. per sq.ft.
Permissible range for crack-free and pore-free plate	150 to 350 amp. per sq.ft.

Much of the favorable comment about bright crack-free and duplex chromium is viewed with restraint by C. H. Sample, International Nickel Co., Inc., who expressed his opinions on "The Contributions of Nickel and Chromium to the Durability of Decorative Plating". His conclusions are based on observations of copper-nickel-chromium coatings on steel as well as zinc die castings. While acknowledging that heavy deposits of chromium above the usual 0.01-mil thickness have proved beneficial when applied over bright nickel (with buffed dull nickel the reverse seems to be true), Mr. Sample points out that initially these coatings were not acceptable because of extensive crazing. Heavy crack-free chromium deposits and duplex chromium admittedly show promise. However, more service experience is needed with them before they can be properly judged, while duplex nickel with conventional chromium is practical and field-proven.

*Courtesy of W. H. Safranek, H. R. Miller, and C. L. Faust, Battelle Memorial Institute.

Improved Light-Alloy Castings . . . a Continental Appraisal

*By L. J. G. VAN EWIJK**

After indicating the properties of modern alloys, the author emphasizes that cooperation between designer and foundryman must be improved before full profit can be had from the advantages of light metals, and suggests how this can be achieved.
(A-general, E-general; Al-b, Mg-b, 17-51)

THERE CAN BE LITTLE DOUBT but that, in our modern world of rapidly growing technical developments, the demand for cast products is also bound to grow at a rapid rate – not only because of those traditional advantages such as freedom of shape, economical and fast production, low labor charges, but also because of the versatile adaptability and the high quality which cast products can now offer.

Undoubtedly the light casting alloys – relatively new though they are – will play an important part in future progress because of their attractive physical and mechanical properties. In their early existence, *quality* was not their best asset, and the very fact that – even so – they could give satisfactory service was more than a little due to the simplicity of the pieces and the modest requirements of the customer.

But since that time (say in the past 20 years) much work has been done in this field and many important advances have been achieved. Existing light alloys were improved, and several new alloys (magnesium alloys in particular) have become available. New production processes such as Antioch†, shell molding, and low-pressure die casting, and new ways for controlling quality and production (spectrographic analysis, radiography and penetrant die inspection) have been introduced and proved their value. In many ways, the interest of designers and potential users was stimulated and the attention of the public was strongly drawn toward the newer materials by advertising, demonstrations, exhibitions, aviation contests and publicity about missiles and satellites.

But if the interest grew, so did the requirements. New needs arose, specifications became more definite, inspection more severe. Metallurgists and foundry engineers had to join hands and strive to keep pace with the rapidly growing demands, for the range of applications widened and the list of properties and charac-

*Consulting Metallurgist, Wenum, Apeldoorn, Netherlands.

†Gypsum-sand molding process devised by Morris Bean; *Metal Progress*, March 1952, p. 51.

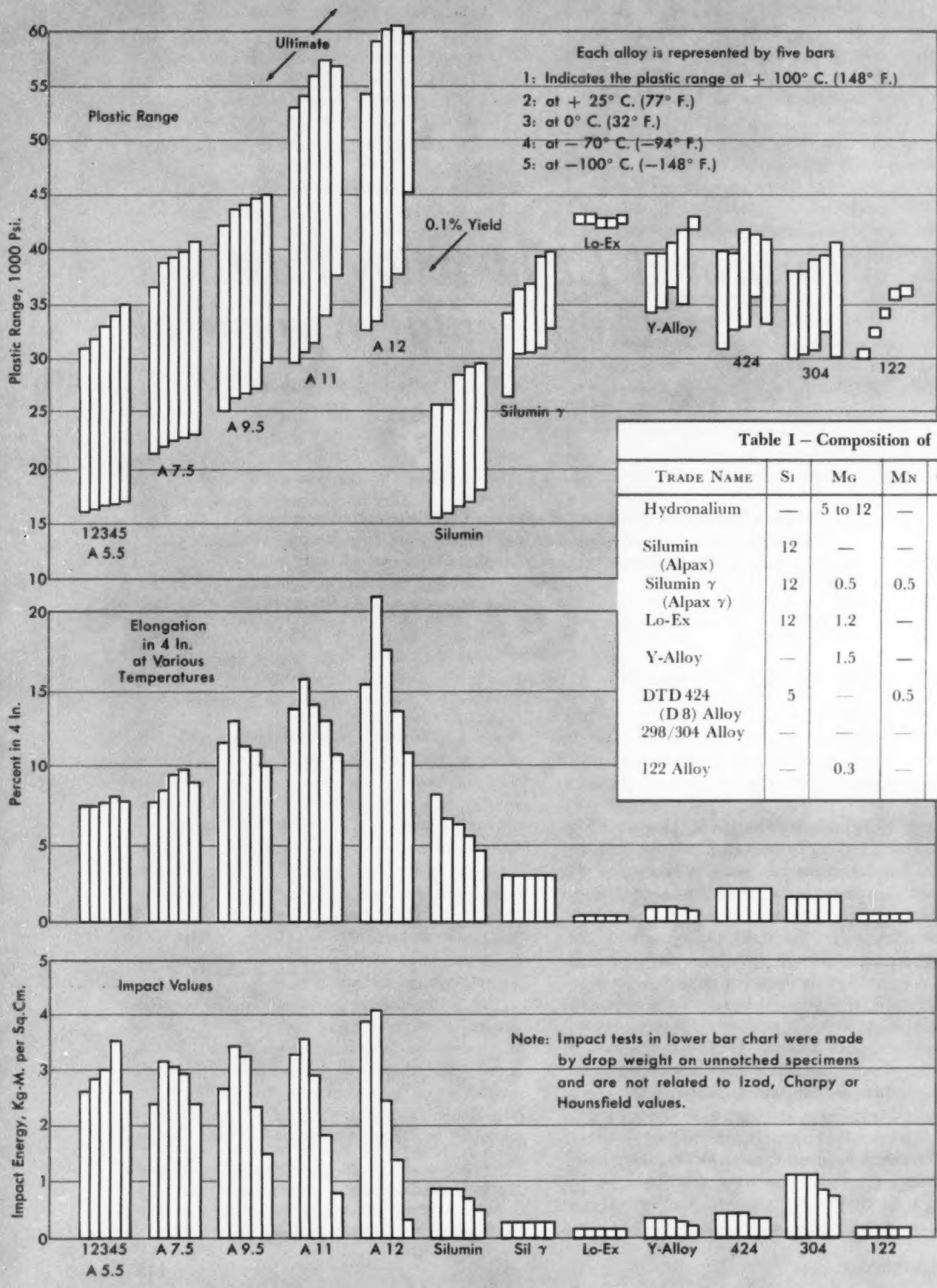


Table I – Composition of Aluminum

Trade Name	Si	Mg	Mn	Cu	Ni
Hydronalium	—	5 to 12	—	—	—
Silumin (Alpax)	12	—	—	—	—
Silumin γ (Alpax γ)	12	0.5	0.5	—	—
Lo-Ex	12	1.2	—	1	2.5
Y-Alloy	—	1.5	—	4	2.1
DTD 424 (D 8) Alloy	5	—	0.5	3	—
298/304 Alloy	—	—	—	4.5	—
122 Alloy	—	0.3	—	10	—

teristics lengthened. The latter can on occasion be of primary importance; let us mention a few of these:

Appearance – finish, polish, color.

Accuracy – tolerances, dimensional stability.

Machinability.

Resistance to corrosion, with or without any protection.

Strength or strength-weight ratio.

Fatigue.

Creep.

Surely not *all* of these requirements could be met by one or two alloys. So out of the tremendous number of aluminum alloys proposed in recent years a group of typical foundry alloys has grown to be of major importance to the European metals industry. Each one possesses

Casting Alloys

Equivalent Specifications
BS 1490; LM.10.W (Mg 10%);
A.S.T.M. G 10 A (Mg 10%); 220 Alloy
BS 1490; LM.6.M;
A.S.T.M. S 12 A
BS 1490; LM.9.WP
BS 1490; LM.13.WP;
A.S.T.M. SN 122 A
BS 1490; LM.14.WP;
A.S.T.M. CN 42 A
BS 1490; LM.4.WP;
A.S.T.M. SC 8
BS 1490; LM.11.WP;
A.S.T.M. C 4 A
BS 1490; LM.12.WP;
A.S.T.M. CG 100 A

one or several of the desirable characteristics which by study and experience could be brought up to the level desired by the purchaser. In addition to the aluminum alloys shown in Table I, a number of magnesium alloys – several of them with remarkably good properties – have been added to the list of earlier compositions needed by the foundryman (Table II). The mechanical properties of the aluminum alloys are indicated in the full-page chart opposite and some information on the mechanical properties and practical behavior of the magnesium casting alloys is given in Table III.*

Fig. 1 – Mechanical Properties of Aluminum Casting Alloys in Wide Use in Europe. Top bar chart shows plastic range – proof stress (or 0.1% yield) to ultimate – at five indicated temperatures between +100 and −100° C. See footnote to text at right for description of drop test used for data in lower bar chart. Alloys A 5.5 to A 12 are Al-Mg ("Hydronalium") alloys; the numeral signifies the magnesium content

The tables give the trade names in frequent use in Europe. Equivalent British and American specifications are noted in Tables I and II. Only the typical compositions and properties are given. For alloys responding to various heat treatments, representative properties resulting from the heat treatment producing the higher yield and ultimate strengths are indicated. The bar charts and tables for both aluminum and magnesium casting alloys summarize the extensive tests carried out by the writer and his staff.

Aluminum Casting Alloys

Looking at these tables and graphs, we can realize that both the constructor and the foundryman have much to choose from. Also it will be evident that, with respect to strength properties, the aluminum-magnesium alloys rank very high – especially those containing the higher percentages of magnesium. Another valuable feature of the aluminum casting alloys is their very good resistance to corrosion, which, combined with their extremely good appearance when highly polished, suits them for varied applications. For the construction or design engineer, a possible drawback of the aluminum casting alloys containing above 7% magnesium is that they are increasingly sensitive to aging. Since this aging causes a severe loss of properties, they are not suitable for long service at moderate temperatures. No stabilizor (to prevent precipitation of the beta phase from the supersaturated solid solution) is known as yet.

In the foundry these alloys are far from easy; especially in the more complicated pieces, it can be very difficult to attain proper feeding and to control properly the directional freezing. Such castings must be very carefully designed and very carefully handled in all phases of foundry technique, if sound structural parts such as heavily stressed airplane components (Fig. 2)

*A brief description of the impact tests shown in Fig. 1 should be appended. It was devised by the author and determines the minimum fall of the tup to break a cast test piece, with notch cast in. In the work reported here, the 1-cm. square bars were cut from notched slabs 1 cm. thick. (No other machining was done.) The notch is a straight groove, 2 mm. wide, with semicylindrical bottom. Gap in the anvil is 8 cm. wide; the tup is wedge-shaped with edge rounded to 2 mm. Weight of the tup is adjusted so the fall is at least 1 meter.

Table II – Composition of Magnesium Casting Alloys

Trade Name	Al	Zn	Mn	Zr	Rare Earths	Th	Equivalent Specifications
Z 5 Z	—	3.5-5.5	—	0.4-1	—	—	DTD 711 and 721 A A.S.T.M. ZK 51 A
RZ 5	—	3.5-5.5	—	0.4-1	0.75-1.75	—	DTD 738 and 748 (no A.S.T.M.)
TZ 6	—	5.2-5.8	—	0.4-1	—	1.5-2	DTD 000 (M 40)
Z RE 1	—	0.8-3	—	0.4-1	2.5-1	—	DTD 708 A.S.T.M. EZ 33 A
MCZ	—	—	—	0.4-1	2.5-4	—	DTD 728 A.S.T.M. EK 30 A
Z RE 0	—	0.3-0.7	—	0.4-1	2.5-4	—	DTD 718
ZT 1	—	1.7-2.5	—	0.4-1	—	2.5-3.5	A.S.T.M. HZ 32 A
A 8	7.5-9	0.3-1	0.15-0.4	—	—	—	BS L 121 and L 122 A.S.T.M. A 8
AZ 91	9-10.5	0.3-1	0.15-0.4	—	—	—	BS L 123, L 124 and L 125 A.S.T.M AZ 91 and AZ 92
C	7.5-9.5	0.3-1.5	0.15 max.	—	—	—	

Table III – Average Mechanical Properties and Outstanding Characteristics of Magnesium Casting Alloys
(Black-face figures represent notable values)

Trade Name	0.1% Yield	Ultimate	Elongation in 2 In.	Fatigue Strength (*a*)	Impact (*b*)		Hardness (*c*)	Outstanding Characteristics (*d*)
					Unnotched	Notched		
Z 5 Z	**21,000**	**37,000**	8%	11,200	1.0	0.4	70	1 (2)
RZ 5	20,000	31,000	**4**	**12,700**	0.5	0.2	70	**1, 2,** 3
TZ 6	**21,000**	**40,000**	10	11,200	1.0	0.2	70	**1, 2,** 3
Z RE 1	13,000	23,000	5	10,100	0.7	0.2	55	**1, 2,** 3, 4(250° C.)
MCZ	13,000	23,000	5	9,600	—	0.2	55	**1, 2,** 3, 4(250°C.)
Z RE 0	Similar to Z RE 1			—	—	—		**1, 2,** 3, 4(250° C.)
ZT 1	13,000	28,000	8	10,100	0.8	0.2	55	2, 3, **4**(325° C.)
A8	13,000	36,000	10	11,900	**2.3**	0.6	55	
AZ 91	14,000	33,000	3	8,700	0.8	0.4	**80**	2 (die castings)
C	14,000	31,000	2	10,800	1.7	0.4	75	Cheapest alloy for general purposes

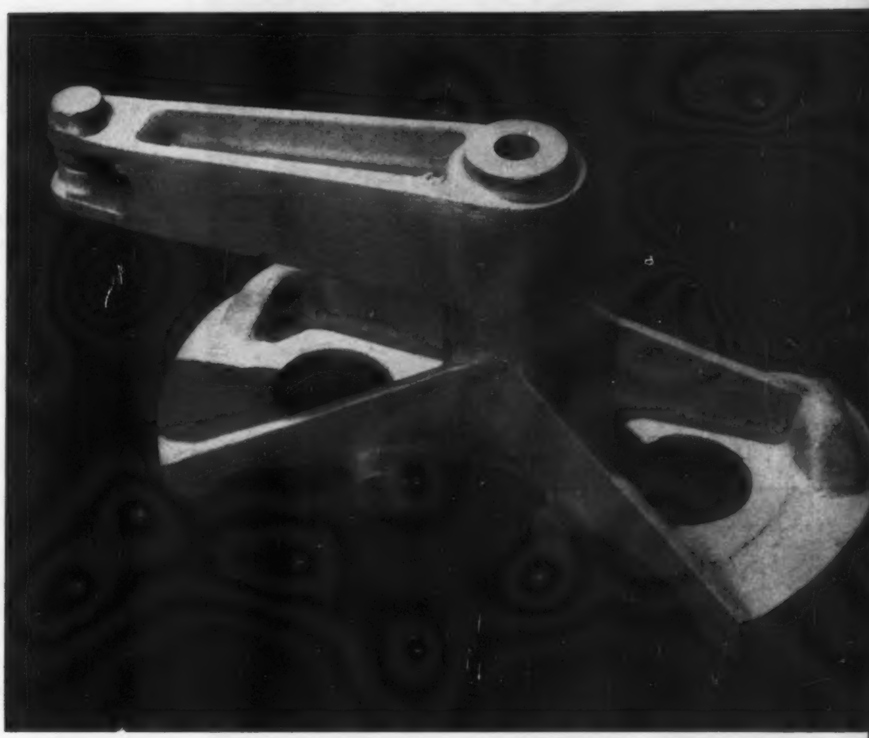
(*a*) Endurance for 50,000,000 cycles; Wohler test, unnotched specimen.
(*b*) Impact figures are in kg-m. The notched bars represent values for Hounsfield specimen and figures approximate the Izod values.
(*c*) Brinell test, 10-mm. ball, 500-kg. load, 30-sec. duration.
(*d*) 1 = Good castability.
2 = Freedom from porosity, good pressure tightness.
3 = Good weldability.
4 = Good creep resistance.

are to be produced. That they can meet severe specifications if handled rightly and can give satisfaction under heavy service is proved by much experience in many applications.

Of the other aluminum casting alloys Silumin and Silumin γ are perhaps the most popular because of their excellent castability and suitability for the production of pressure-tight castings. In plasticity Silumin comes nearer to the Hydronaliums than the other alloys. The resistance to corrosion of the Silumins, though lower than that of Al-Mg group, is good. Consequently they are much used in marine applications.

Lo-Ex and 122 Alloy (both piston alloys) resemble each other in strength; both show a very low elongation, but this is no serious drawback for their principal use. Lo-Ex is much in demand for its low thermal expansion (about 19 $\times 10^{-6}$ per °C.). Alloy 122 is known to be more resistant against attack by fatty acids. Both are difficult to handle in the foundry.

Fig. 2 – Aircraft Component of Sand-Cast Hydronalium (Al, 10.5 Mg). Courtesy Industrie-Vaassen



Y-Alloy, too, is in use for pistons and for cylinder heads as well. Although its Brinell hardness is lower (about 120 for sand castings as against 135 to 145 for 122 Alloy and Lo-Ex), Y-Alloy has proved its value for applications demanding high performance.

Alloy D 8 (DTD 424) is a general purpose alloy, much in use for applications where no heavy stresses occur. Its foundry behavior is good. For high dimensional stability a stress-relieving heat treatment is favored.

Being a copper alloy, 304 is not an easy performer in the foundry. Its strength and plasticity are of the same order as that of D 8 but its impact resistance* is better and can surpass even that of Silumin if heat treated correctly.

Magnesium Casting Alloys

The magnesium alloys in Table II are grouped according to the absence or the presence of aluminum as an alloying element. Those containing aluminum are the older members of the family. Of these A 8 is still used a good deal in Europe although perhaps not as much as in the United States. Its tensile properties, in comparison with the newer aluminum-free alloys, are very good; the impact resistance of unnotched specimens is remarkably high (see Table III). In the foundry it is prone to microporosity and requires very careful foundry techniques. Even at best it can be very difficult to achieve complete soundness. A beautiful casting in A 8 is shown in Fig. 3.

AZ 91 is a die-casting alloy, very suitable for general purposes. Its strength and ductility are good, its toughness rather poor. With sufficient care it is suitable for castings which have to be pressure tight. If handled properly, it is possible to attain a high degree of dimensional accuracy, as for instance is shown by the intricate casting in Fig. 4. Magnesium alloy C is also much used for general purposes.

The newer aluminum-free alloys show several remarkable advances in the metallurgy of light alloys. T. E. Leontis mentioned some American innovations in his article "Magnesium in Missiles and Aircraft" in *Metal Progress* for November 1959. In such usage their high damping

*The Hounsfield impact machine used for much of our work has two pendulums, one of which carries the test piece. They are swung back and tripped simultaneously, meeting at dead center. The test piece is cylindrical, 8 mm. (0.315 in.) diameter, 1.75 in. long, with 45° machined notch 0.0835 in. deep, bottom radius 0.010 in.

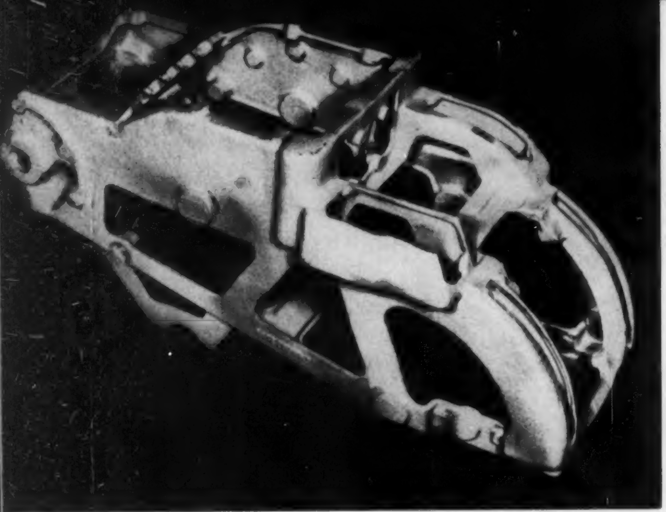


Fig. 3 – Dual Control Bracket for Passenger Plane; Magnesium A 8 Alloy, Sand Cast. (Courtesy Sterling Metals Ltd.)

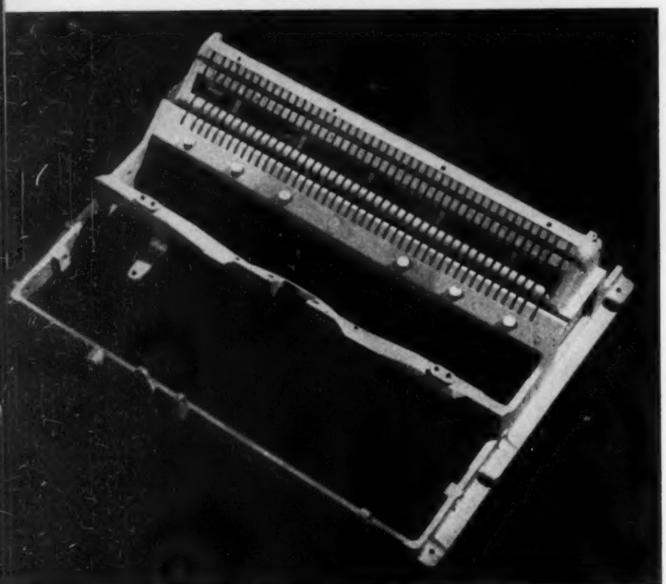


Fig. 4 – Typewriter Frame in AZ 91 Magnesium Alloy, Die Cast. (Courtesy Industrie-Vaassen)

Fig. 5 – Component of Fokker Friendship in RZ 5 Magnesium Alloy, Sand Cast, Heat Treated. (Courtesy Industrie-Vaassen)

capacity, superior compressive yield strength and high specific heat are of great advantage. He notes, however, that "the conventional alloys continue to predominate in castings". This approximately parallels the situation in Europe, about which the present author is writing.

At the head of the list in Tables II and III is Z 5 Z, the first new alloy to offer a considerably higher proof stress to the constructor, at the same time bringing to the foundry an alloy much less prone to microporosity. European foundrymen soon became familiar with the very special techniques it requires in melting and refining and appreciated the quality that could then be obtained.

RZ 5, although a bit lower in strength, soon became popular because it could make absolutely sound castings of the most intricate designs. Of the "Elektron-Magnesium" alloys so far studied, the TZ 6 alloy containing zirconium and thorium is the strongest. Its foundry behavior is the same – or almost the same – as that of RZ 5. Both RZ 5 and TZ 6 are weldable, while Z 5 Z is not. Figure 5 shows an example of an important aircraft component cast in RZ 5.

Z RE 1 is a remarkably good alloy for pressure tightness – equal to Silumin in this respect, or perhaps even a bit better. It also has good creep resistance up to 250° C. (480° F.).

MCZ has properties which are about the same as those of Z RE 1 but its impact resistance is better. Z RE 0 is a variant of Z RE 1, with equal creep resistance, but with somewhat higher corrosion resistance.

ZT 1, one of the two magnesium alloys containing thorium, offers a combination of several valuable characteristics. The most important of these is the high creep resistance up to 325 or 350° C. (650° F.).

Cooperation Between Designer and Foundryman

So much for the inherent capabilities of our present casting alloys based on the light metals aluminum and magnesium. How can we be assured that these potentialities are used, not wasted?

It will be clear from the foregoing summary that a wide range of properties and characteristics is available for the many and varied applications of today. But it should also be clear that close cooperation between designer and foundryman is indispensable to achieve good results. It stands to reason that more and closer cooperation will be needed for complicated

pieces than for simple pieces. However, appearances often deceive, even in the foundry, and it is an established fact that a seemingly "easy" casting can prove most difficult if tight specifications have to be met. Therefore it is safe to say that without adequate cooperation between purchaser and vendor no first-class results can be expected.

But isn't that cooperation good enough now?

In order to answer this question, let us consider what "cooperation" usually has been.

The designing engineer who, with a definite object in mind, decided to use a casting, started his drawing and "molded" his piece on paper. As a good designer, he knew the principles of casting design; he was fully aware that dimensional transitions have to be gradual, that abrupt changes of section are bad, that sharp corners are worse, and that there is a minimum limit to wall thickness. Also he knew the mechanical test properties of the alloy he had in mind, or at least, he knew where to find them.

After completing his design (seldom earlier), he or his purchasing agent wrote to a foundry or two or went to them with his drawings and invited their offer of price and delivery date. The foundry manager studied the drawings and specifications, formed his opinion about the general conditions the pieces had to meet, the number or series wanted, the desired terms of delivery and the price. In many instances – the really simple ones or those where earlier experience could help him – this wasn't too difficult, so he could make an offer and accept the order without undue risk.

But on many other occasions he wouldn't feel too certain, for several reasons. Maybe the alloy requested wasn't very suitable, or perhaps not at all. Possibly the design didn't seem too skillful and alterations were necessary. Sometimes alterations are feasible, sometimes not; the designer perhaps was already bound to shape and dimensions. Very often trial castings and development of the casting technique would be necessary before the founder could come to a definite conclusion as to the suitability of the analysis. If the designer or customer could not allow time for these developments, and the foundry offered terms of delivery and prices without sufficient knowledge about production difficulties, it could easily happen that deliveries would already be in arrears and the profit gone before production actually started! Later came the added danger that the quality would suffer by hurry, all the while the customer would impatiently be demanding delivery.

This unpleasant situation is a good example of insufficient cooperation between designer and foundryman. Cooperation starting with a letter inviting an offer on castings according to enclosed drawings is not "in proper time." It is more often too late.

Of course, this was in "the old days"!

But is it so much better nowadays? Doesn't a more or less similar situation still arise frequently? Perhaps the writer is too severe in believing that designer and foundryman are not close enough. In his opinion, design engineers and foundry engineers have unconsciously grown too far apart. Both have developed their expert knowledge to meet the requirements of modern techniques, but their mutual contacts have not developed accordingly. A sound, high-class casting of today requires more than merely an adequate designer, a suitable alloy and a responsible foundry. Only by really close cooperation will it be possible to convince skeptics that their reluctance to use castings for heavily stressed parts of airplanes, road vehicles and machinery is quite unfounded.

How to improve cooperation is not an easy problem to solve, but let us look at it in this way: After all, the designer is the architect and the founder is the builder of the piece. The founder is in possession of the materials – the possibilities – and the designer has to ask for them. In order to know what he should ask for, he has to understand many things which cannot be mastered in an engineering course and which are not to be found in books or catalogues. It is not enough that the designer be "foundry minded"; he must learn to think in foundry terms. There lies the biggest difficulty. There is no other way to think in foundry terms than by experience – by working in a foundry long enough to understand the difficulties which must be surmounted in making a sound casting of high quality.

By way of compromise the purchasing firm might engage an expert foundryman as consultant. But his advice will be appreciated only if the designer, too, is able to "think foundry"; otherwise his help won't mean much.

In coming years, the demand for light castings will increase. This cannot be doubted. But for the high-class castings that modern engineering industries will require, a much closer cooperation between founder and designer than exists today is necessary.

All-Position Arc Welding

*By A. LESNEWICH**

Transferring metal from electrode to weldment by high-frequency short circuits rather than across an arc gives new versatility to gas-shielded metal-arc welding. Thinner sections can be joined and welding can be done from any position. (K1d)

THE DEVELOPMENT OF the consumable-electrode arc with inert-gas shields has permitted easy fabrication of once difficult-to-weld metals, such as aluminum, titanium, and stainless steels, of heavier section thicknesses than could be handled with the inert-gas-shielded tungsten-arc process. The use of inert atmospheres for consumable-electrode welding offers many advantages. Metal transfer occurs by discrete droplets and is spatter-free, the arc length is self-regulating, and easily oxidized elements of the alloys are retained in the weld. With few exceptions, carbon steels, however, have not been welded with inert-gas-shielded arcs, since the cost proved too great compared with that of the older methods such as the covered electrode and submerged arc.

Lower costs resulted with the introduction of carbon dioxide as a shielding gas for welding mild or low-alloy steels. This saving was somewhat offset by the disadvantages resulting from the substitution. Because carbon dioxide is an oxidizing atmosphere at arc temperatures, electrodes containing an excess of deoxidizers must be used. This adds to the cost of the process.

In addition, carbon dioxide shielding may generate substantial spatter, which wastes weld material, spoils the appearance of the weldment, and accumulates in the apparatus where it disrupts the gas shield. Spatter can be minimized only by carefully regulating current, voltage, and wire feed to maintain a very short apparent arc length; that is, the arc is maintained substantially beneath the plane of the work surface.

A limitation in some instances of the consumable-electrode process regardless of gas shield is the inherent high heat input to the work. Metal being transferred across the arc from the electrode is at or near its boiling temperature. As a result, a relatively large and fluid pool is produced that is difficult to control except when welding in the flat position. In vertical or overhead welding, the pool will either sag or run out unless it is dammed or otherwise controlled by manipulation. This problem is not as aggravating when welding aluminum since relatively low-current arcs may be used and the high thermal conductivity of the base metal permits a rapid quench of the weld pool.

A second limitation in consumable-electrode welding of thin sections is the penetrating character of the arc. Unless high speeds are used, the arc may sever rather than weld.

Improved Method

These shortcomings of the gas-shielded consumable-electrode welding process can be minimized, if not eliminated, by modifying the welding power supply, and using lower arc voltages and smaller electrode diameters.

*Supervisor, Welding and Joining, Metallurgical Research, Central Research Laboratory, Air Reduction Co., Inc., Murray Hill, N.J.

These changes have resulted in a new method of welding called "Dip-Transfer"* in which the transfer of metal is entirely by high-frequency short circuits rather than through the arc stream.

Dip-Transfer can be used to weld thin and heavy sections in all positions. This is accomplished with very little spatter loss, in a shield of either carbon dioxide or inert gas, and by welders having little experience.

High-Frequency Short Circuits

The mechanism of Dip-Transfer has been studied rather extensively with the aid of oscillographs and ultra-slow-motion pictures. These studies show that metal transfers to the pool from the electrode only when the two are in contact with up to 200 short circuits occurring each second. As a result of this mode of transfer, the molten metal does not become superheated, and spatter is virtually eliminated.

Such transfer is possible only if the static voltage supplied by the power supply is less than that required to sustain a stable, open arc; the open-circuit voltage also must be low. In addition, the power supply, along with the other components of the electrical circuit, must have a value of inductance that will regulate the rate of rise and decay of current within rather critical limits. Under these conditions, a pulsing arc is achieved.

With consumable-electrode welding, the electrode is fed mechanically at a steady rate, on the order of 4 to 5 in. per sec. The feed rate is high enough to allow stability of transfer even during manual welding. Oscillations produced at the tip of the constantly advancing electrode are diagramed schematically in Fig. 1. Shown here are the effects of current and voltage on the weld pool and the electrode tip.

The moving electrode can be assumed initially to have been driven into the weld pool, creating a short-circuit load on the power supply, and consequently causing the current from the machine to surge to a very high value that is dependent upon the design of the power supply. Before the maximum peak value is reached, however, heating is caused by the resistance to the flow of current at the interface of the electrode and the weld pool. Surface tension pulls some metal from the electrode as shown in Fig. 1 A; and shortly thereafter, with an assist from electromagnetic pinch effect, the contact is broken, as with an overloaded fuse,

*Trademark.

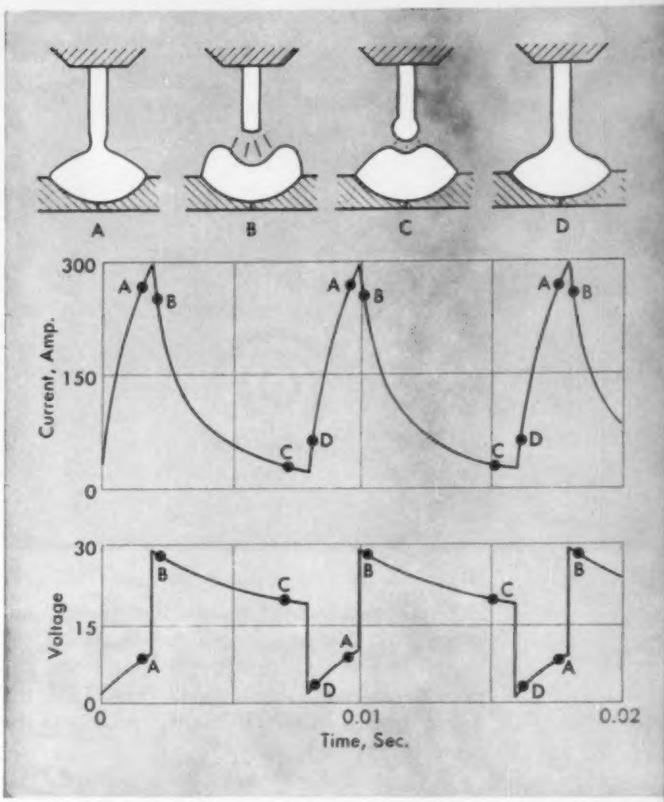


Fig. 1 – Schematic Diagram of Metal Transfer Mechanism and Voltage and Current Wave Forms Associated With Dip-Transfer Technique. A – Surface tension helps break contact at tip of short circuited electrode; B – With contact broken, high inductance creates strong arc which depresses weld pool; C – Melting electrode closes gap as decaying voltage and current weaken the arc; D – Electrode and pool contact, liquid drop is transferred, cycle repeats

and a relatively high-current arc is created.

Energy of the arc helps melt the electrode and keeps the weld pool fluid; it comes in a large part from energy stored in the electrical inductance during the interval of short circuiting. The dissipation of this energy is accompanied in an early stage by a transient arc voltage which is caused by the rapid breaking of an inductive electrical circuit and is larger than that available from the power supply under static conditions. The arc develops considerable force which creates a depression in the weld pool (Fig. 1 B).

As the energy from the inductor is discharged to the arc, voltage and current decay, the forces on the weld pool decrease and the melting

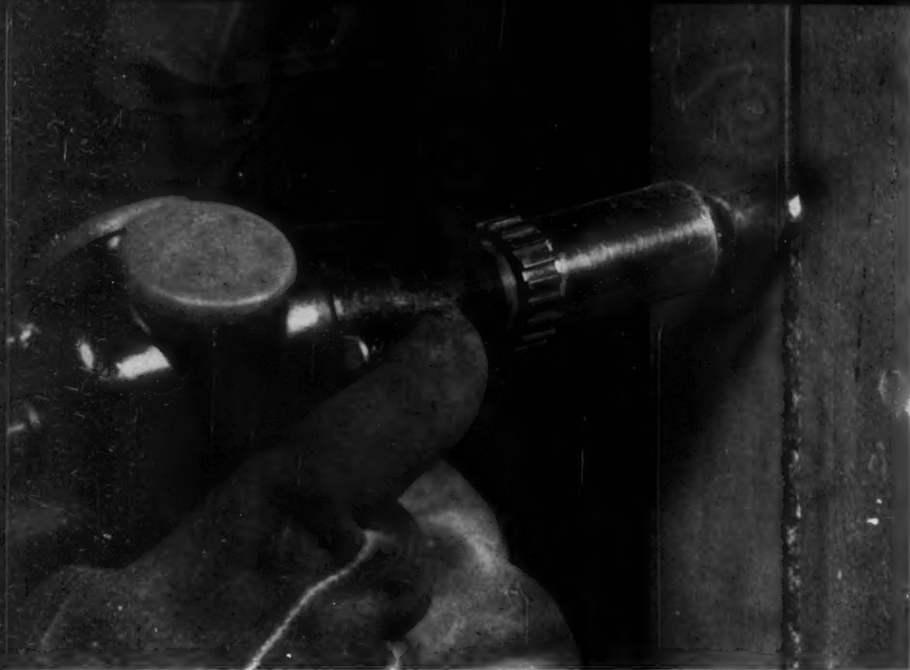


Fig. 2 – *Typical Dip-Transfer Gun Shown Here Butt Welding Vertical ¼-In. Plates*

electrode is advanced toward the work. Consequently, the arc length is decreased, as shown in Fig. 1 C. Finally, the electrode and pool again come into contact (Fig. 1 D), the liquid drop is transferred to the pool, and the cycle is repeated.

The period of each cycle is very uniform. It is determined by the inductance of the circuit, the voltage setting of the power supply, the diameter and extension (length between the gun and the arc) of the electrode, and the rate at which the electrode is fed to the arc. Under the most desirable conditions, the cycle repeats itself between 100 and 200 times per sec.

Effect of Variables

The frequency of oscillation varies inversely with the inductance. If inductance is too low, the peak current increases to the point where excessive spatter is generated and splashing of the pool may produce cold laps along the edges of the weld. When inductance is too high, large drops form at the electrode tip, greater welding skill is required, arc length fluctuates, and spatter losses increase. The deposit may have poor penetration and be excessively convex. Increasing the electrode diameter, the welding voltage, or decreasing the speed of electrode feed is equivalent to increasing the inductance of the circuit.

In practice, constant-voltage or rising-voltage power supplies are required for Dip-Transfer welding. External *(Continued on p. 158)*

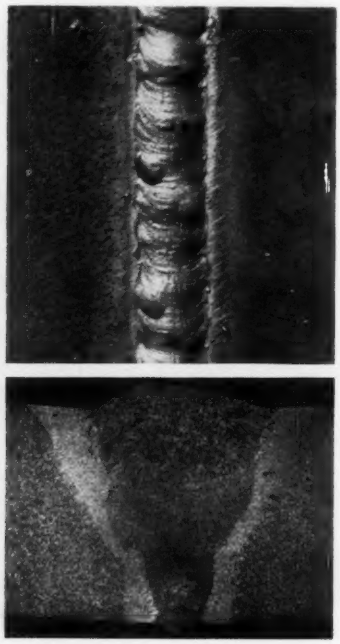
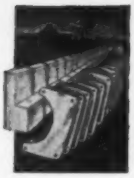


Fig. 3 – *(Left) Surface View of a Vertical Fillet Weld in 1/16-In. Steel Sheet Made by Dip-Transfer Technique. Weld was made with 0.035-in. diameter electrode fed at 120 in. per min., CO_2 shield, at 60 amp., 20 v.*

Fig. 4 – *(Right) Surface (1 ×) and Cross-Sectional Views (2½ ×) of a Butt Joint Made in ½-In. Steel by Dip-Transfer Method With 80% Argon, 20% CO_2 Shield. Weld was made in three passes. Low spatter is characteristic of the technique*



Short Runs

Inclusions Help Identify Stainless Steels

*By R. P. WENTWORTH**

MICRO-EXAMINATION HAS PROVED TO BE a valuable quality control tool at J. Bishop and Co. Platinum Works in Malvern, Pa. The major part of Bishop's 300 series stainless tubing orders are produced from three grades – Types 304, 321 and 347. Quality control requirements are such that a microsection must be prepared from many cut lengths or coils of tubing. For a typical order for capillary tubing, 0.125 in. O.D. × 0.030 in. I.D. for example, as many as 75 tube sections are mounted in a 1¼-in. diameter plastic mold. These are micro-examined to determine (*a*) compliance with specification limitations on radial or sunburst cracks, (*b*) freedom from objectionable amounts of carbon or nitrogen, (*c*) grain size, and (*d*) adequate heat treatment as revealed by grain structure. Dimensional requirements are also checked with a filar eyepiece.

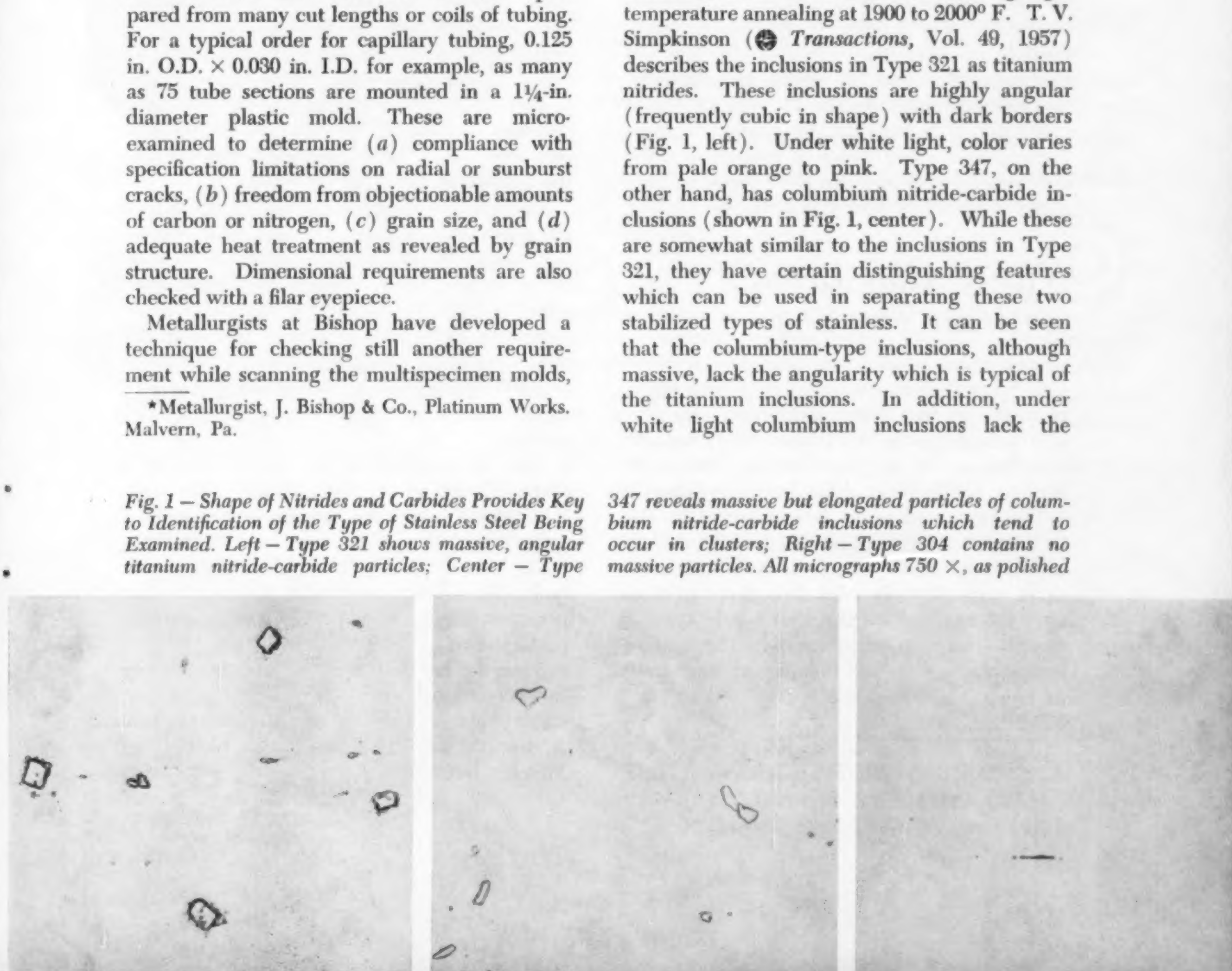
Metallurgists at Bishop have developed a technique for checking still another requirement while scanning the multispecimen molds, namely, the conformance of all specimens to the proper A.I.S.I. Type 304, 321 or 347.

Pinpoints Stainless Grade

It is known that the stabilized austenitic Types 321 and 347 have characteristic massive inclusions which are not dissolved during high-temperature annealing at 1900 to 2000° F. T. V. Simpkinson (*Transactions,* Vol. 49, 1957) describes the inclusions in Type 321 as titanium nitrides. These inclusions are highly angular (frequently cubic in shape) with dark borders (Fig. 1, left). Under white light, color varies from pale orange to pink. Type 347, on the other hand, has columbium nitride-carbide inclusions (shown in Fig. 1, center). While these are somewhat similar to the inclusions in Type 321, they have certain distinguishing features which can be used in separating these two stabilized types of stainless. It can be seen that the columbium-type inclusions, although massive, lack the angularity which is typical of the titanium inclusions. In addition, under white light columbium inclusions lack the

*Metallurgist, J. Bishop & Co., Platinum Works. Malvern, Pa.

Fig. 1 – Shape of Nitrides and Carbides Provides Key to Identification of the Type of Stainless Steel Being Examined. Left – Type 321 shows massive, angular titanium nitride-carbide particles; Center – Type 347 reveals massive but elongated particles of columbium nitride-carbide inclusions which tend to occur in clusters; Right – Type 304 contains no massive particles. All micrographs 750 ×, as polished



characteristic color of the titanium nitride particles; in fact, their color almost matches that of the surrounding matrix.

Figure 1, right, shows an as-polished sample of Type 304. The lack of any massive inclusions in this grade permits its separation quite easily from the stabilized types.

All incoming stock at Bishop is microexamined and, at the same time, is now rapidly checked by observing the shape of the inclusions. This microscopic method can also be used to separate finished parts of mixed types provided the parts have flat surfaces which can be readily polished. Very little metal is removed so there is no problem in keeping within required dimensional tolerances. Although this method of identification is not practical for a large number of parts, it has proved useful for separating small lots. A mirror finish is not necessary to delineate the inclusions satisfactorily, and the total time required to polish and identify one specimen takes but a minute or two.

It should be noted that spectrographic and chemical methods of type checking are destructive and can not be used on finished parts. Possible nondestructive methods which would measure differences in electrical resistivity, magnetic permeability, or thermal expansion could not, it is believed, be applied to these three grades since physical properties differ only slightly if at all. Even if successful, such methods would be costly and time-consuming.

Nickel Alloy Retort for Heat Treating

ONE EXAMPLE OF GOOD DESIGN, wise choice of materials, and sound fabrication technique is a new lightweight furnace retort recently installed in the bright annealing line of the Ansonia, Conn., plant of the American Brass Co.

The fabricated retort is approximately 31½ ft. long, 42 in. wide, and 23½ in. high. Made of 3/16-in. thick Incoloy nickel-chromium sheet, it is uniformly thick throughout to eliminate the unequal stresses that would occur if section sizes changed abruptly. The new retort replaces one which weighed nine times as much. It was fabricated by Rolock, Inc., Fairfield, Conn.

Incoloy has been successfully employed in many high-temperature applications. Nickel (32%) and chromium (21%) give the alloy the necessary strength, ductility, and resistance to oxidation required for such service. It is readily weldable and can be fabricated by common methods. Although currently used at 1300 to 1380° F. at American Brass, the alloy has given long trouble-free service at temperatures up to 1850° F.

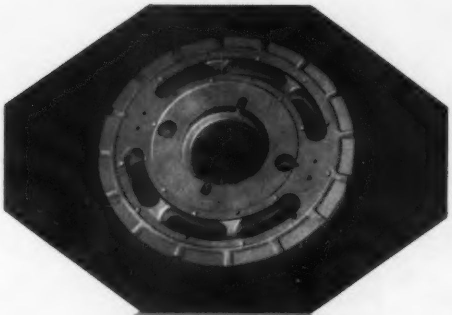
Construction – The design of the retort is unusual. Its arched top and two sides are round-corrugated to provide strength and greater area of exposure to heat. The bottom is box-corrugated for the same reasons. It provides an inside surface on which conveyer chain wearplates can be mounted. Box corrugations also stiffen the retort enough so that no solid foundation is required. End flanges made of mild steel are welded to the nickel-chromium sheet with Inco Weld "A" rod, made specifically for welding dissimilar metals.

Improved Heating – Two longitudinal rows of bricks about 2 ft. apart support the retort in the continuous bright annealing furnace. Both the retort and furnace are made in sections. The north section, where the coils of wire are loaded on the conveyer by hoist, is heated by three natural gas burners beneath the tube. The internal temperature of the retort is only about 30° F. below the furnace temperature. Previously, to obtain 1300° F. in a cast steel retort, it was necessary to operate the furnace at 1560° F.

Steam Atmosphere – Brass and bronze alloys are annealed in a steam atmosphere in the retort. Long hoods on either end of the furnace serve as heat seals, keeping the steam contained within the retort at a slightly positive pressure. Each hood is securely bolted to the mild steel retort flange and is supported at its free end by casters that ride with expansion and contraction of the retort during heating and cooling.

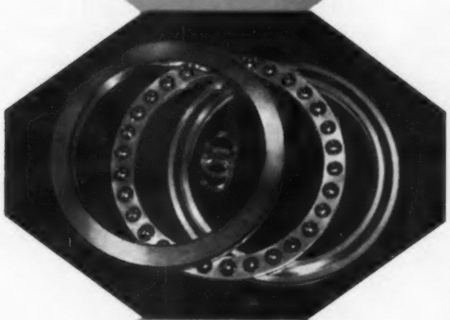
Wire is quenched at the furnace exit in a soapy solution of circulating water. The soap lubricates the wire for redrawing and seals it against oxidation. The hood at this end extends beneath the water level of the quench tank. As the hot coils enter the water, they generate the steam which fills the retort as a protective atmosphere.

Since the installation of the new retort early in 1959, it has been in operation 24 hr. a day, six days a week. On Sunday, the temperature is dropped to 750° F. for quick heat-up on Monday morning.



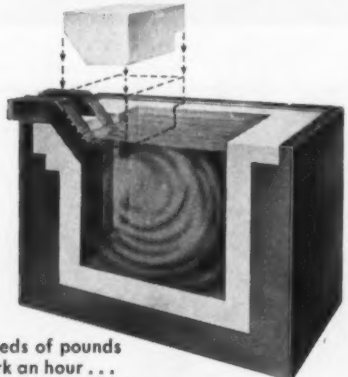
Martempering tamed this heat treater's "nightmare"!

This Vasco B. B. steel valve plate is 11⅜" in diameter and varies in section from ½" to 1⅝". Ajax austenitizing and martempering followed by air cool and draw hardens it to Rc 63-64 on the lighter sections and to Rc 60-64 on the 1⅝" section — without cracking, distortion or surface defects.



Assuring bearing race hardness . . . without distortion.

Freedom from distortion and extreme surface hardness are essential to these 52100 steel bearing races. Ajax austenitizing with Ajax cataract quenching plus air cool and draw supply these characteristics in full measure—on a fast production basis.



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In hundreds of applications throughout industry, Ajax neutral hardening salt baths are providing far and away the fastest, most economical means of heat treating valuable high alloy steel materials.

- Furnace productive capacity is several times that of other methods because of safe, yet faster heating.
- Negligible distortion inherent in the salt bath method means virtual elimination of rejects and decreased finish-machining costs.
- Built-in surface protection guards against scaling, decarb and pitting.
- Unsurpassed hardening uniformity is assured by accurate temperatures that do not vary more than a small fraction of 1% in any part of the bath.

In addition, Ajax salt baths use minimum floor space, are readily adaptable to mechanization and require little maintenance. For instance, the new Ajax Type R removable submerged electrodes can easily be changed in an hour or two per pair — by your regular maintenance men — without tearing down pot or furnace walls.

Actual heat treating results on your own parts, under typical conditions, will be gladly demonstrated in the Ajax Metallurgical Service Laboratories. *You try before you buy!*

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SALT BATH FURNACES

Internally heated electric and gas-fired types

Circle 876 on Page 48-A

CORRESPONDENCE

Caustic Cracking of Steel Pipe

PORT ARTHUR, TEX.

Recently we had a failure of caustic-carrying pipe at the Port Arthur Works of Texaco, Inc., similar to that described by the writer in "Caustic Cracking of Welded Steel Plate", *Metal Progress*, November 1947, p. 803. The interesting feature of this current pipe failure is the particularly mild conditions under which it occurred.

The pipe in question, a part of the pipe line of the water treating plant connected with the power plant, was installed in February 1950 during the construction of the power plant. Constructed of welded pipe, the line is used to unload caustic from tank car to storage tank intermittently once a month; this is carried out at ambient temperatures and pressures not over 40 lb. After the tank car has been unloaded, the line is blown with air. The pipe was not stress-relieved and has the following chemical analysis: Pipe, 0.15% C, <0.04 S, <0.04 P, 0.04 Si; ell, 0.17 C, <0.04 S, <0.04 P, 0.13 Si. The line was installed above ground and fillet welded to suitable supports.

The cracked pipe is shown in Fig. 1. The visible crack was in a circumferential direction and in the weld metal only. Another sample of the straight portion of the pipe contained two surface welds where the pipe was fillet welded to the

Fig. 1 – Cracked Weld in Pipe Used in Unloading Caustic

Fig. 2 – Macroetched Section of Pipe Through Center of Weld in Outside of Periphery of Pipe. 4 ×

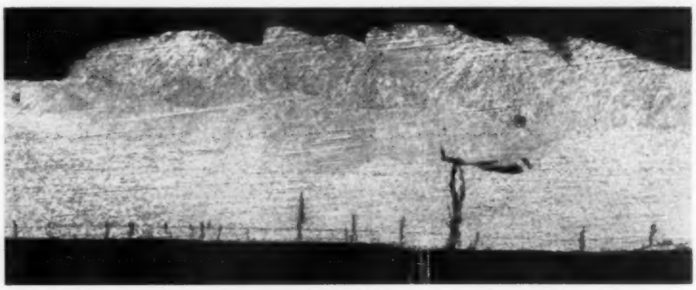
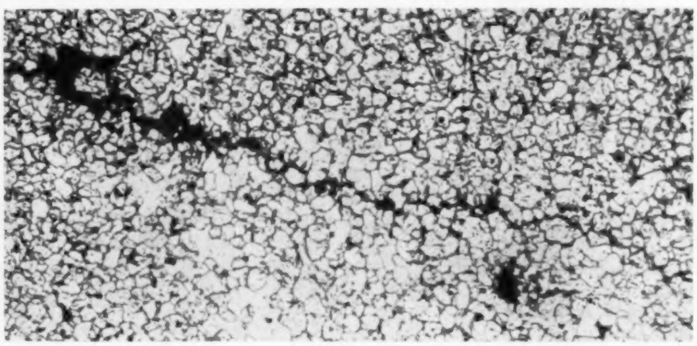


Fig. 3 – Intercrystalline Cracking of Weld Metal; Nital Etch, 250 ×

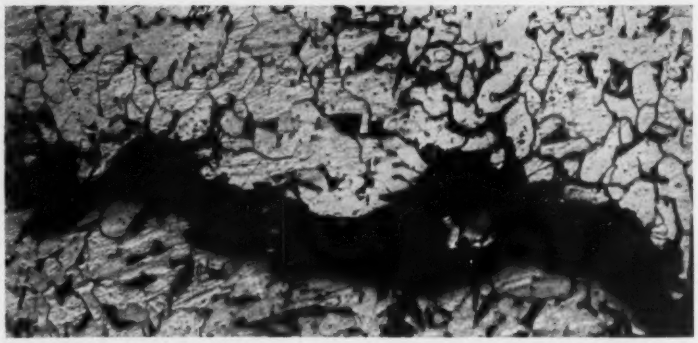


Circle 877 on Page 48-A

supports. Along one of the welds, the surface of the pipe was cracked. There were no cracks on the outside surface of the pipe in the location of the other weld. However, a longitudinal section of the pipe through the center of the weld showed numerous cracks of varying height. The etched portion of this section of pipe is shown in Fig. 2.

Microscopic examination of the main crack showed it to be intercrystalline (Fig. 3). Cracks in the vicinity of the weld were found near the heat-affected zone of the pipe and also in the ell near the weld. The cracks were intercrystalline in all instances (Fig. 4 and 5).

Cracking occurred despite the mild conditions. The stresses involved were thermal stresses resulting from welding, and these stresses were only



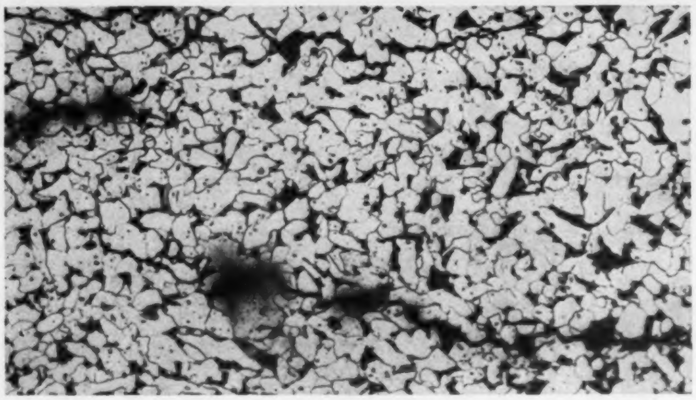


Fig. 4 (Top) – Intercrystalline Cracking of Pipe Metal; Nital Etch, 150 ×. Fig. 5 (Bottom) – Intercrystalline Cracking of Ell; Nital Etch, 150 ×

nominal for the fillet welds and relatively thin pipe (3/16 in. thick). Moreover, the corrosive environment was also very mild and no effects of corrosion were evident in the inside of the pipe.

H. M. Wilten

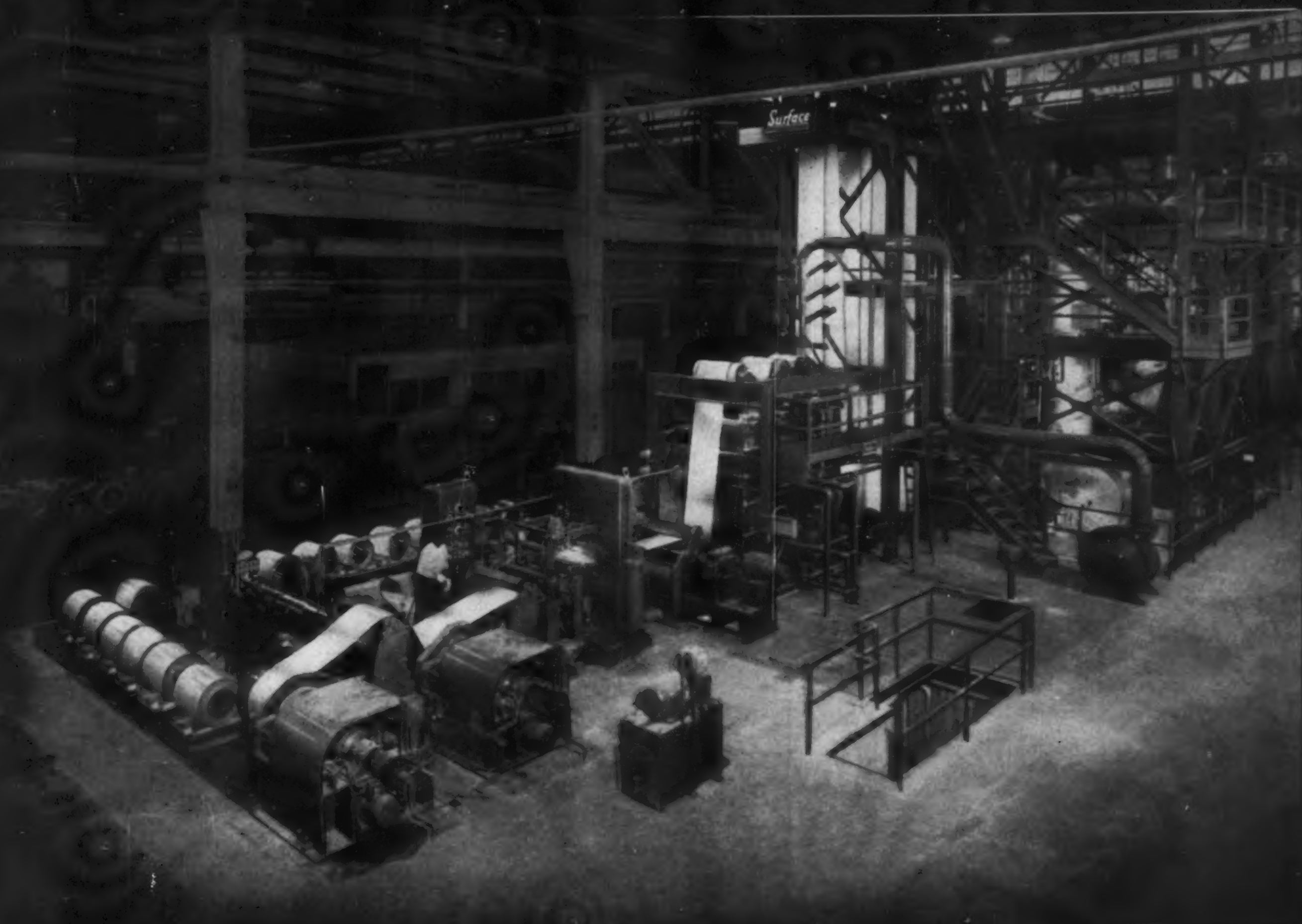
Porosity in Aluminum Alloy Welds

New Kensington, Pa.

A digest of my paper "Porosity in Aluminum Alloy Welds" appeared on p. 188 in the December 1959 issue of *Metal Progress*. In the fifth paragraph, however, the first sentence is somewhat confusing. It should read: "Degassed 5052, 5056 and commercial 3004, 5052, 5056 5154 alloy plate gave porosity ratings below 1½ for up to six passes, wheras *highly gassed* 5052 and 5056 alloy plate gave porosity ratings increasing from 3 for one pass to 4 to 5 for six passes."

Likewise, the last sentence of the fifth paragraph should read ". . . Mg_2Si *with surface* moisture *on* the plate . . ."

F. R. Collins
Process Metallurgy Div.
Aluminum Co. of America



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Circle 879 on Page 48-A

PERSONAL MENTION

R. F. Mehl

W. A. Mudge

Since January 1, R. F. MEHL has been in Europe as consultant for scientific liaison between U. S. Steel and various universities and research institutes in Europe. With headquarters in Zurich, Switzerland, Dr. Mehl has no detailed itinerary – his job will be to look for new knowledge wherever it develops and to promote a more active exchange of scientific people between this country and Europe. Dean of graduate studies and head of the department of metallurgy, Dr. Mehl is on an indefinite leave of absence from Carnegie Institute of Technology. A graduate of Franklin and Marshall College and Princeton University, he has been at Carnegie Tech since 1932 when he became director of the Metals Research Laboratory. (A biographical appreciation of Dr. Mehl appeared in *Metal Progress*, September 1953, p. 74.)

W. V. Clipsham – from home office consultant for the Chicago and Detroit region for Riverside-Alloy Metal Div., H. K. Porter Co., Inc., to sales office manager.

A glance at the masthead of this issue of *Metal Progress* will show an addition to our staff of consulting editors – W. A. MUDGE. Bill Mudge hardly needs an introduction to *Metal Progress* readers – or indeed to any metallurgist. His work with International Nickel Co. over a nearly 40-year span (culminating in his retirement in December 1958) is well known; his discoveries have included age hardening of nickel and commercial procedures for producing nickel-clad and nickel-alloy clad steels, and he has some 25 patents in his name. Coming to Inco in 1920 as a research metallurgist, he became director of technical service in 1947 and at his retirement was assistant to the president as special representative on educational programs. (For a more detailed report of his career and contributions to metallurgy, see the biographical appreciation which appeared in *Metal Progress*, July 1958, p. 87.) Beginning with the fall 1960 semester, he will be an instructor in metallurgy at New York University.

His first job as consulting editor is already in print in this issue – the report on p. 101 of the Symposium on the Industrial Uses of Radio-Isotopes held in Philadelphia in mid-January.

Henry M. Heyn, president of Surface Combustion Corp., Toledo, was named vice-president in charge of the Surface Combustion Div. of Midland-Ross Corp., after the latter company acquired the assets of Surface late last year. Mr. Heyn has been with the surface organization for 38 years, joining the company as a draftsman and advancing through the engineering and sales operations. He was appointed vice-president and general manager of the industrial division in 1956 and two years later elected president of the company.

Walter A. Dean succeeded **William T. Ennor** as assistant director of research for Aluminum Co. of America following Mr. Ennor's retirement. Dr. Dean joined Alcoa's research laboratories in New Kensington, Pa., in 1929, moving to Cleveland two years later; he was named Cleveland Works chief metallurgist in 1949. He was transferred to Pittsburgh in 1957 as assistant development metallurgist and later became development metallurgist in the metallurgical division.

A chemical engineering graduate of the University of Wisconsin, Mr. Ennor came to Alcoa's technical direction bureau in New Kensington in 1924. He subsequently served in various Alcoa plants in the east and in 1948 returned to New Kensington as assistant director of research of the Alcoa Research Laboratories. One of his outstanding accomplishments during his 35 years with Alcoa was his invention and perfection of the continuous ingot casting (DC) process.

Personals . . .

Reginald V. Williams, president and director of research, Williams Gold Refining Co., Inc., Buffalo, N. Y. – named recipient of the 1959 Frank J. Tone Award awarded annually by the Niagara Frontier Section of the A.I.M.E. in recognition of outstanding and important contributions to the science and practice of metallurgy.

R. K. Hopkins – to vice-president and general manager of the Steel Div., Firth Sterling, Inc., Pittsburgh.

J. Ernest Hinzman – from manager of production at the Kidd Works of Vulcan-Kidd Steel Div., H. K. Porter Co., Inc., Aliquippa, Pa., to manager of research and development of the division.

David P. Moore, Sr. – from service metallurgist at the Louisville, Ohio, plant of Jones & Laughlin's Stainless and Strip Div., to supervisor of quality control.

George L. Flint – from sales manager, southern district, for Mallory-Sharon Metals Corps., Niles, Ohio, to western district sales manager, supervising sales in nine western states with headquarters in Hollywood, Calif.

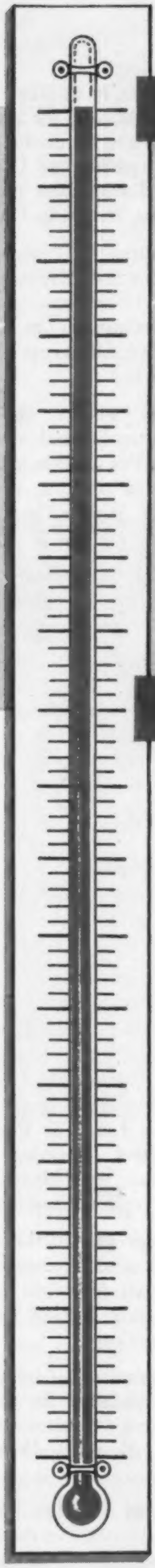
William A. Grant – to district sales manager, electronic controls section, for the Budd Co., Philadelphia, with headquarters located in Los Angeles.

Howard C. Myers, Jr. – from general superintendent of testing and inspection for Midvale-Heppenstall Co., Philadelphia, to director of metallurgy.

John W. Lynch – to manager of sales, special products, Carpenter Steel Co., Reading, Pa., working with the product sales managers and the field sales force in developing new business for the company's vacuum melting facilities.

Robert O. Johnson–from head of the Consolidated Vacuum Corp. district office in Palo Alto, Calif., to manager of the western regional sales and service office, responsible for the Pacific Coast states, the Southwest and the Rocky Mountain states, with regional headquarters in Palo Alto.

Metallurgical Memo from General Electric



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Operator checks molten alloy in furnace beneath him where temperatures range from 2500° to 3000° F. Vacuum-induction melting makes René 41 or any composition virtually free from impurities and inclusions which reduce causes of premature structural failures.

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Circle 882 on Page 48-A

Personals . . .

John E. Cottier, Jr. – from position in charge of sales for products of the Detroit and Louisville plants of Jones & Laughlin Steel Corp., to Los Angeles district sales manager of the Stainless and Strip Div.

John H. Sutton – formerly in charge of carbon and alloy strip sales on the West Coast, now assistant district sales manager in Los Angeles for Jones & Laughlin Corp.'s Stainless and Strip Div.

D. Gardner Foulke – from manager, electrochemical development, Hanson-Van Winkle-Munning Co., to research director, precious metals division, Sel-Rex Corp., Nutley, N. J.

George H. Hatfield – opened his own manufacturer's agency, Hatfield and Co., in Dallas, Tex.

Vernon E. Adler – now employed by the New York Operations Office of U. S. Atomic Energy Commission as technical contracts administrator for research and development metallurgy contracts and as technical consultant for metallurgical problems.

Milton R. Watko – from chief engineer, machine division, International Conveyor & Washer Co., to chief engineer, Ransohoff Co., Hamilton, Ohio.

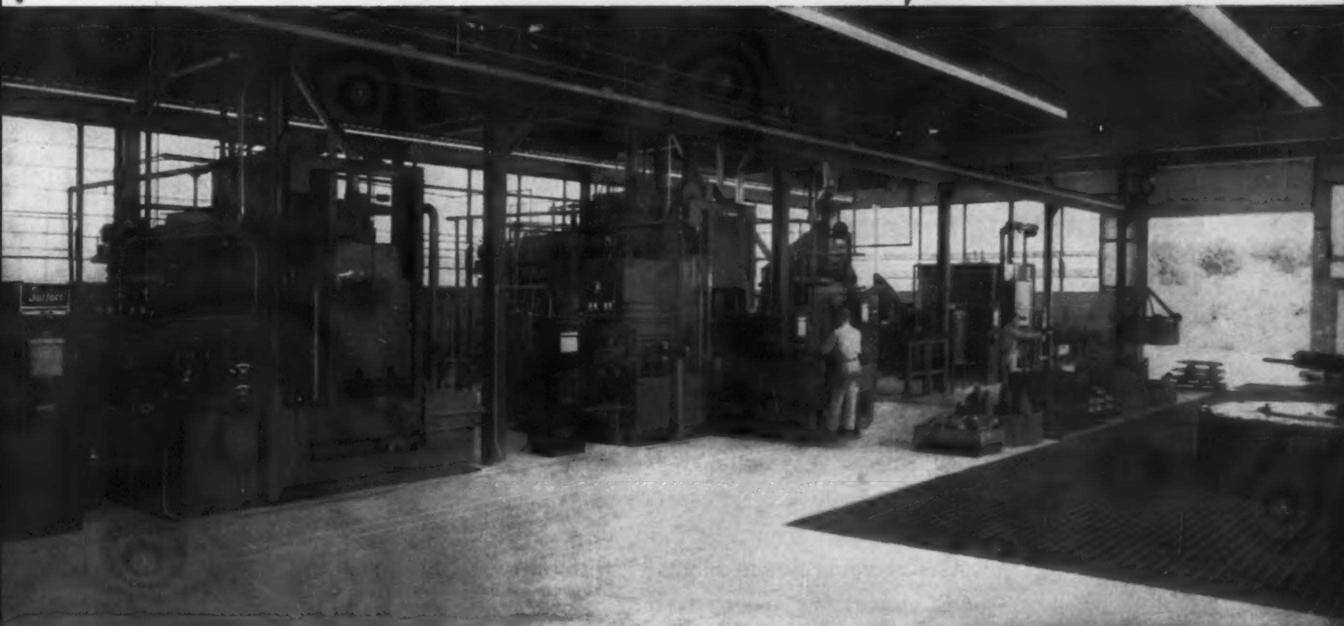
C. Robert Weir, Commonwealth Industries, Inc., Detroit – elected president of the Metal Treating Institute. **John H. Ries**, Lakeside Steel Improvement Co., Cleveland, and **Lloyd G. Field**, Greenman Steel Treating Co., Worcester, Mass., were elected vice-president and treasurer, respectively.

E. L. Phillips – to the newly created position of regional manager, West Coast operations for the Stainless and Strip Div., of Jones & Laughlin Steel Corp.

John L. Zambrow – from manager of the metallurgy department, Sylvania-Corning Nuclear Corp., Bayside, L. I., N. Y., to director of engineering.

Joseph Rey – appointed to the new Detroit sales office of the Riverside-Alloy Metal Div. of H. K. Porter Co., Inc.

stop temperature variations in high density loads with SURFACE POWER CONVECTION



Exceptional uniformity and speed of heat treating, regardless of load density, help make a consistent profit-maker of this mechanized line of Surface batch-type furnaces at The Milwaukee Gear Company.

Because of Surface Power Convection, Milwaukee Gear has much greater metallurgical control and uniformity of product than ever before. High-velocity wind penetrates the tightest loads; assures uniform heat transfer whatever the size, shape, or alloy of the work.

Carburizing case depths are hit right on the button which vary from a few thousandths to 3/16 of an inch. This unusually flexible standard rated furnace line consists of two Super Allcase® furnaces, a horizontal draw furnace, spray washer, DX® and RX® gas generators, and Autocarb® signalling dewpoint controller.

Surface Power Convection cuts cycle times to a fraction.

These advantages only suggest the profitability of Surface Power Convection. Ask your Surface representative to describe the most important development in convection heat transfer in 20 years.

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Circle 884 on Page 48-A

Surface

Personals . . .

Waldemar Naujoks – now supervisor of die planning, National Forge Co., located in Irvine, Warren County, Pa.

P. L. "Static" Willson – retired after 15 years as chief metallurgist for Halliburton Oilwell Cementing Co. and is now a consulting metallurgical engineer in Duncan, Okla.

James Henderson – from purchasing agent and production manager to plant superintendent for Chester Cable Corp., Chester, N. Y.

Charles R. Funk – from manager of metallurgy and engineering, Alco Products, Inc., Latrobe, Pa., to chief metallurgist, Eastern Div., Colorado Fuel and Iron Corp., with headquarters at the Claymont, Del., plant.

John H. Frye – from manager of sales, Bar Div., Columbia Steel & Shafting Co., Carnegie, Pa., to vice-president of the Bar Div.

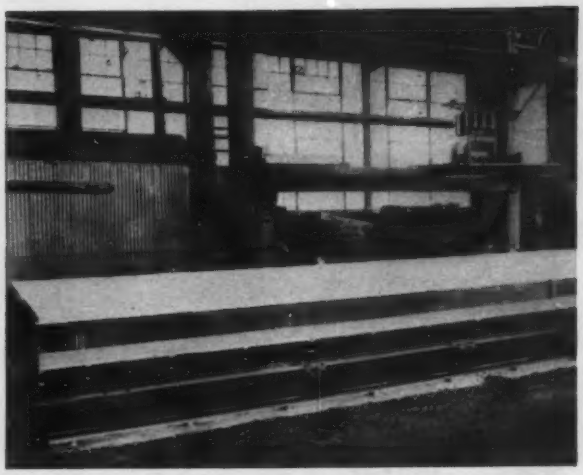
J. C. Reid – now vice-president in charge of sales, heat treatment furnaces and metallurgical products, Birlefco-Lindberg Limited, Toronto, Ont. The company was formerly Efco-Lindberg Limited; however, Birlec-Efco (Melting) Limited of England, a subsidiary of Associated Electrical Industries Limited, recently acquired a 50% interest in the company, hence the subsequent name change. **B. Evans** is the new vice-president in charge of melting furnace sales.

Richard A. Grayson – from metallurgist, Inland Mfg. Div., General Motors Corp., to metallurgist, research department, Mack Trucks, Inc., Plainfield, N. J.

Brian P. Yates – for many years secretary of Low Moor Alloy Steelworks Limited, Low Moor, Bradford, England and its associated companies, Yorkshire Rolling Mills Limited and Low Moor Fine Steels Limited, and a director of Brayshaw Furnaces Limited, has been elected to the Board of Directors of Low Moor Alloy Steelworks Limited.

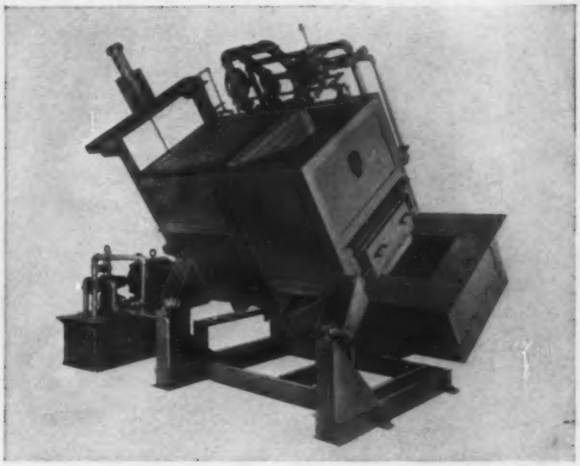
Richard C. Cunningham, vice-president in charge of sales for Eastern Stainless Steel Corp. – elected to the board of directors of the company.

In this stress-relieving furnace, B&W Kaocrete-D is used on the floor ledges, car top, in the door jamb and at the end of the flat roof where it withstands the abrasion of the door. This material is specially designed to withstand severe abrasive conditions and mechanical abuse.



Heavy duty car top service requires a high strength castable. B&W Kaocrete-D is excellently suited for this service at temperatures to 2500 F. B&W Kaocrete-32 is recommended for service above this range.

B&W Kaocrete-32 has been cast to form the curb walls of a soaking pit. When mechanical abuse from ingots damages the curb, Kaocrete-32 has the necessary properties to localize the damage, thus maintaining the serviceability of the rest of the curb.



The castable lining of this aluminum reverberatory furnace must have unusually high strength to withstand the considerable physical abuse of charging, operating and cleaning, while resisting the penetration of the molten metal. Kaocrete-D is widely used in this application.

How B&W refractory castables solve abrasion problems

Refractory castable linings used in metal-working furnaces are often subjected to severe mechanical abuse. Scraping by hand tools, loading and unloading, and the action of the molten metal and particle-laden gases all affect the life of refractories. Among B&W's line of refractory castables are two that are particularly suited to withstand unusual abrasive conditions. They are B&W Kaocrete-D and B&W Kaocrete-32, both of which have been used successfully in many demanding applications.

B&W Bulletin R-35A gives additional information on versatile B&W refractory castables. Write for copy to The Babcock & Wilcox Company, 161 East 42nd Street, New York 17, N.Y.

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Fabrication of Rare Earth Metals

Digest of "Mechanical Fabrication of Rare Earth Metals", by K. M. Bohlander, and "Forming and Fabrication of Yttrium Metal", by J. M. Williams and C. L. Huffine. Papers presented at the ⊕ National Metal Congress, Chicago, November 1959.

DURING THE LAST FEW YEARS, the rare earth metals and yttrium have emerged from the role of laboratory curiosities to fulfill unique requirements for engineering materials. Yttrium has been investigated thoroughly and work on gadolinium has revealed much about its properties. The other rare earths and scandium have received less attention. However, because of the closely associated properties of the rare earths, the mechanical fabricability of one is generally related to others in the group.

Melting – Due to their extreme reactivity with oxygen, the rare earths must be melted and cast in an inert atmosphere or a vacuum. Yttrium, dysprosium, gadolinium, erbium and samarium have been induction melted and cast in small graphite molds with 0.02% carbon pickup. Lanthanum, cerium, praseodymium, neodymium and yttrium have been cast in tantalum at a pressure of 100 to 200 microns.

Gadolinium, terbium, dysprosium, holmium, erbium and lutetium, because of their somewhat higher vapor pressures, are cast at an absolute pressure of about 10 in. mercury. Ytterbium, samarium, thulium and europium, due to their high vapor pressure, are generally cast at a pressure of two atmospheres of argon. Several ingots of yttrium metal, 7½ in. in diameter, weighing about 100 lb., have been produced by arc melting sponge in a vacuum.

Rare earth metals ordinarily crystallize with considerable grain size and contain varying amounts of both inter and intra-granular inclusions. In general, the fewer the number of inclusions the larger the grain size upon casting.

Primary Mechanical Working – Working the rare earth billet is necessary to refine the grain size and improve the structure of the metal. Deformation brings about an increase in elongation and toughness as well as a general increase in strength. Working of the rare earth metals can be done both hot and cold and involves extrusion, forg-

Table I – Corrosion Rates of Rare Earth Metals in Air (Mg. per Sq.Dm. per Day)

TEMPERATURE:	95° F. (35° C.)		203° F. (95° C.)		392° F. (200° C.)	752° F. (400° C.)	1112° F. (600° C.)
RELATIVE HUMIDITY:	1%	75%	1%	75%			
Lanthanum	80	950	510	21,000	30	3,200	13,000
Cerium	—	—	—	—	—	200,000	—
Praseodymium	8	76	900	5,500	80	38,000	130,000
Neodymium	2	7	60	2,000	70	380	4,800
Samarium	0	0	0	100	15	17	35
Gadolinium	1	2	0	35	0	210	16,000
Terbium	0	0	0	—	0	1,600	40,000
Dysprosium	0	0	0	43	—	350	6,600
Holmium	1	1	1	—	11	110	5,400
Erbium	1	1	0	—	10	90	720
Ytterbium	—	—	—	—	—	170	—
Yttrium	1	1	2	9	4	40	1,900

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Rare Earth Metals . . .

ing, rolling and swaging processes.

Due to the greater number of slip planes in the face-centered cubic lattice of cerium and ytterbium and the body-centered cubic lattice of europium, these metals are more readily worked in any direction than are the other rare earth metals. Yttrium and scandium, due to their hexagonal lattices, are only deformable parallel to the basal plane. In cold working, the hexagonal metals undergo progressive work hardening which limits the degree of cold work that may be applied. Cold worked metals are restored to their maximum softness and workability by annealing. Hot working above the recrystallization temperature can be carried out with large reduction and no work hardening.

Gas Pickup – A severe deterrent to fabricating rare earth metals is their extreme affinity for reactive gases (oxygen and hydrogen in particular). Of the light subgroup, only samarium and gadolinium do not react appreciably with air at room temperature to form the oxide. The heavy, less reactive rare earths, including yttrium and scandium, do not oxidize at room temperature. However as the working temperature is raised, the corrosive effect of air becomes more pronounced. Except for the few metals which can be worked at room temperature without work hardening effects, the rare earths must be worked or annealed at elevated temperatures and protected either by cladding or inert atmospheres to prevent metal loss. Table I gives data on corrosion rates of rare earth metals in air.

In general, fabrication studies on rare earth metals extending through several years show an improvement in room-temperature workability. During this time, the amount of interstitials (principally oxygen) has decreased seven-fold for the element yttrium. Recent advances in reduction and purification processes have produced yttrium metal having oxygen content in the range of 500 ppm. The ductility of this metal is superior to any yttrium previously produced.

Extrusion – A breakdown of arc melted ingots by hot extrusion or forging is a necessary step for subsequent hot working operations.

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Rare Earth Metals . . .

Considerable success has been achieved in forming yttrium, gadolinium and dysprosium rods from arc melted ingots by hot extrusion. Ingots 2 in. to 6 in. in diameter have been extruded into rods 0.6 to 3⅝ in. in diameter. Extrusion temperatures were varied from 900 to 1650° F. with most ingots initially extruded at 1300° F. Due to the reactivity of rare earth metals with air at high temperatures, nearly all of the extrusions were made from ingots clad with a heavy coat of aluminum oxide and a ¼-in. wall copper jacket. The ram speed in all cases was 13 in. per min.

Forging – While not as easy to perform as extruding, forging refines grain size and improves structural properties. Since arc melted billets are susceptible to cracking, the initial deformation must be carried out with caution. It is advantageous to use extruded bar stock for forging whenever possible.

A typical operation to produce an yttrium bar from a 6-in. diameter arc melted ingot begins by heating the 80-lb. round for 3 hr. at 1600° F. in an inert atmosphere. Press forging takes the bar down to 4 in. diameter, with ⅛-in. reductions per pass and intermediate anneals at 1600° F. Forging is done stepwise along the length of the ingot. Following the second or third series of presses, the corners are subjected to a reduction of ⅛ in. to prevent opening of surface defects in the cast ingot. This operation is not necessary for smooth surfaced billets. Uniaxial reduction down to 2-in. thickness prepares the yttrium for further processing.

Rolling and Swaging – After the initial breakdown of the as-cast billet structure, rare earth metals can be readily hot rolled or swaged at temperatures above the recrystallization point. Optimum temperature for rolling and swaging yttrium is 1400 to 1600° F. Since 10 to 25% reductions can be made with each pass, the exposure to air is for only a short time. A small amount of oxide is formed, which is powdery in nature and can be removed by machining or sand blasting. Hot swaging appears to give a better surface than flat or rod rolling. Rods have been swaged at 1450° F. down

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Rare Earth Metals . . .

to 0.022-in. wire for a 91% reduction in diameter. The finish of the wire was excellent, with only a light oxide coating.

The ability to cold work rare earth metals is most affected by the quantity and types of impurities present in the metal. The elements found to be most detrimental (either free or combined) are oxygen, calcium and magnesium.

Work Hardening – Yttrium appears to work harden more rapidly during rolling with several small reductions per pass than with large reductions. In one test the metal was annealed at 1000 to 1100° F. for 10 min., cooled to room temperature under vacuum and cold rolled. With reductions of 2 to 5% per pass, radial cracks developed. However, when reductions on the order of 50% per pass were used, radial cracking was minimized. Reductions up to 99% were achieved this way, and ductile sheet from 0.009 to 0.014 in. thick was obtained.

Ytterbium is reported to be the easiest member of the rare earths to roll into thin sheets (0.1 mm). Samarium can be worked to a similar extent but the other elements from gadolinium to lutetium should be hot worked first and given intermediate anneals during cold working. In general, these heavy elements are more stable and are not as easily worked as the light elements in the rare earth group.

Machining – All rare earths machine with the same ease as yttrium with the possible exceptions of cerium, europium and ytterbium which may require boring operations particularly suitable for very soft metals. Yttrium is considered to be free machining with but minor tendencies toward galling. Finishes of 125 rms. are easily obtained. However, yttrium is hazardous to machine because of its high pyrophoric tendency. In all operations the chips should be as large as possible and under no circumstances should they be permitted to collect, even in small quantities, around the machine. Chips should be stored in drums or metal containers under several inches of a high flash point oil.

In lathe work with yttrium, as in most other jobs, toolsteel or carbide tools may be used. The tool should

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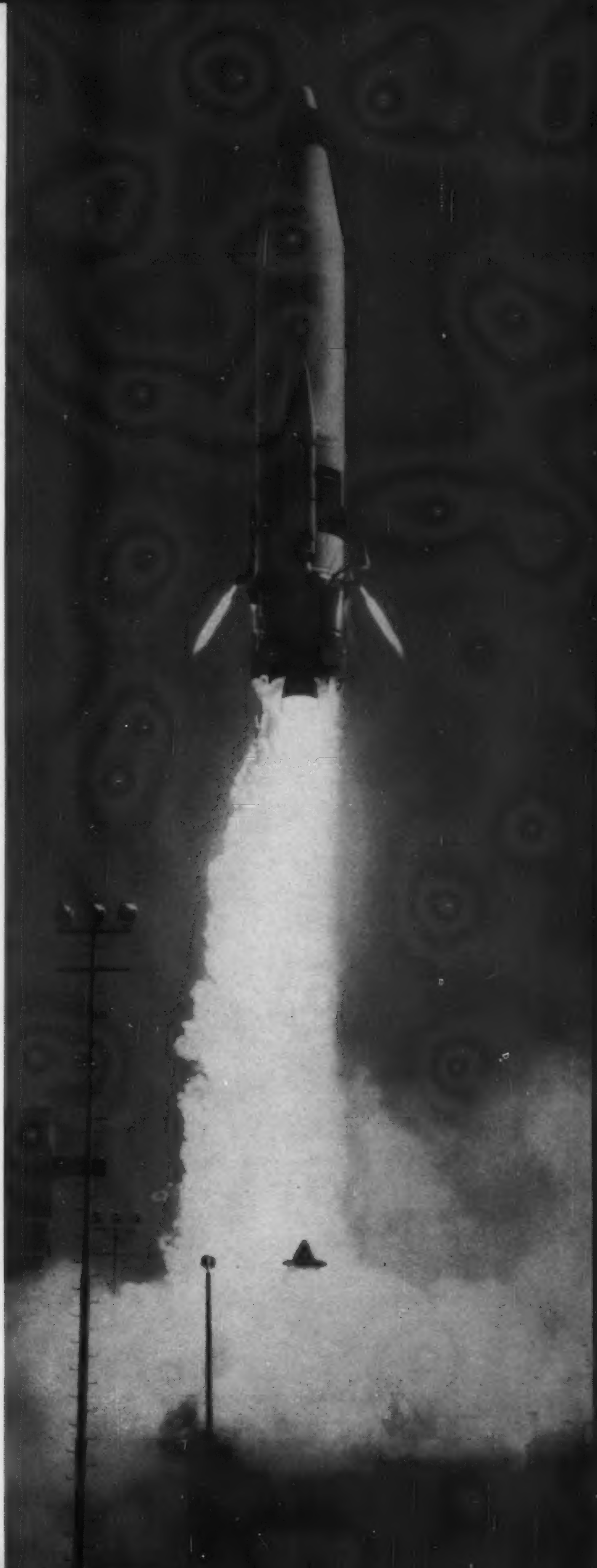

Rare Earth Metals . . .

be ground with a positive rake. With carbide tools, a minimum speed of 300 ft. per min. should be maintained, while with toolsteel, speeds may be 100 to 400 ft. per min. The cut should maintain at least a 0.010-in. chip advance and more, if possible. The larger the chip, the less chance there is for burning. Dry cutting is preferred rather than the use of a lubricant.

Milling – In milling, the speed of cutting depends on the size of the cutter and the number of teeth. As in lathe work, a 0.010-in. minimum chip load is suggested. Every precaution should be taken to keep the work below 140° F., which, in turn, influences the speed of cutting. Dry cutting, which is the preferred method, results in finishes of 125 rms. and better.

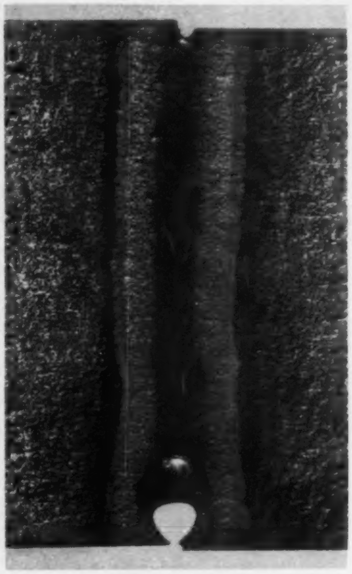

Fig. 1 – Butt Welded Yttrium Made by Inert-Gas Tungsten-Arc Process Without Filler Metal. Although the metal appeared to fuse readily, joints had longitudinal cracks in center of weld upon cooling

For drilling, either high speed toolsteel or carbide-tipped drills can be used. In either case, a positive rake angle and flushing of the drill point with a high flash point oil is advised. Flushing is necessary to free the chips which have a tendency to pack tightly around the drill.

When grinding yttrium, a free-cutting M to P crystalon wheel is required. For lubrication, either a water-soluble or a high flash point oil should be used.

Joining – A study has been conducted on welding yttrium to itself by the inert-gas tungsten-arc process.

Fig. 2 – Less Cracking Occurred in Yttrium Weld When Sheared Strip of the Base Metal Was Used as Filler

Butt weld joints were made on annealed stock, 0.040 in. thick. After shearing to size, the edges were cleaned by vapor blasting, rubbing with an abrasive and washing with acetone. The welding was performed in a vacuum purge chamber, evacuated to 0.1 micron and back filled with argon. Two specimens were welded at 15 amp., without filler rod, and two were welded at 17 amp. with sheared strips of the base metal as filler. Although the metal appeared to melt and fuse readily, all joints exhibited longitudinal cracks through the center of the weld upon cooling. As Fig. 1 and 2 indicate, less cracking occurred when filler metal was added during welding. Yttrium containing 1000 to 3000 ppm. of oxygen was found to be susceptible to cracking when welded.

A.G.G.

(*More digests on page* 152)

Schlieren photograph showing heated air rising from Malleable chain link at 1200° F.

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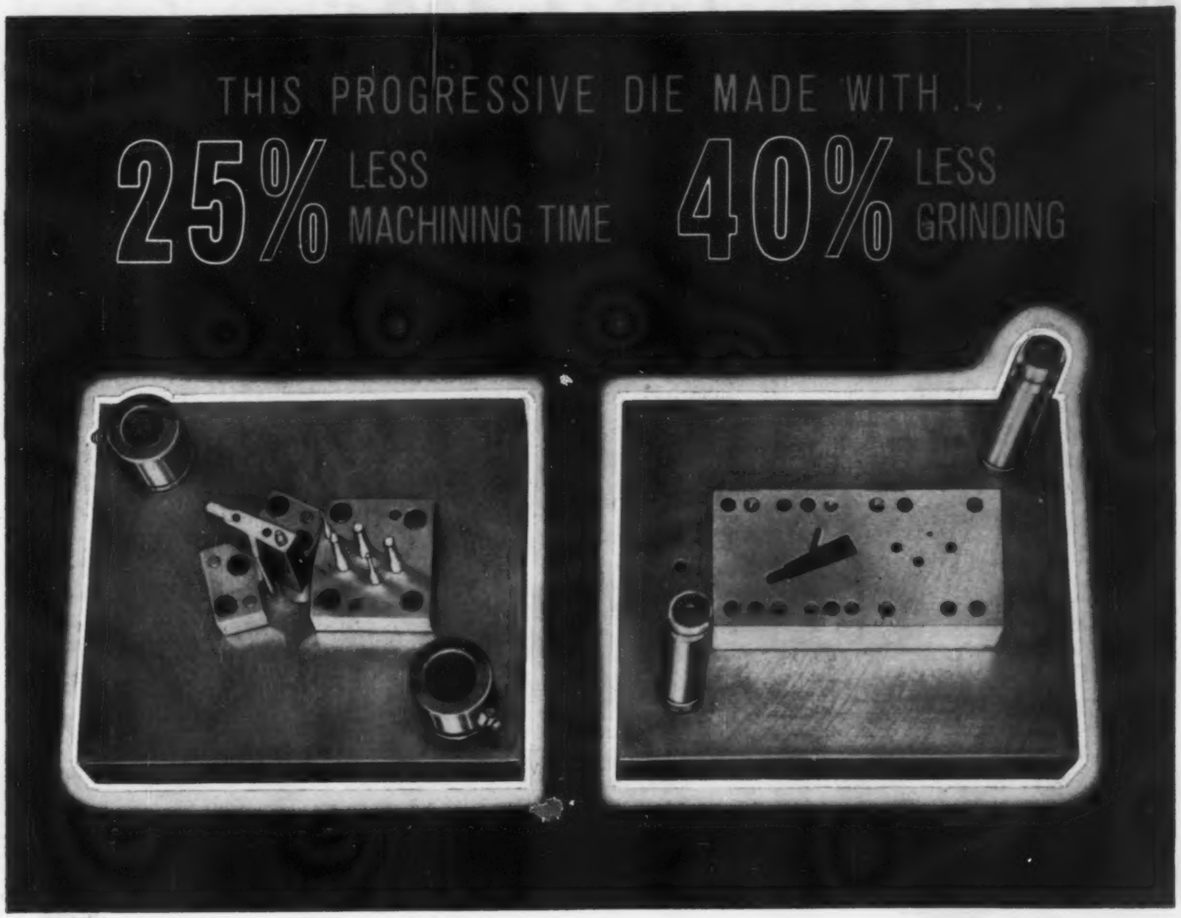

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*Pat. No. 2,422,786; June 24, 1947

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Mr. William E. Brandt

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Stress-Relief of Forgings

Digest of "Effect of Advances in Intermediate Fabrication Techniques of Material Characteristics: Compressively Stress-Relieved Forgings", by R. Smallman-Tew. Paper presented at the ⊕ Western Metals Congress, Los Angeles, March 1959.

THE PAPER discusses principles and practical applications of compressive deformation in the relief of residual stresses in aluminum alloy (X 7079) components of the Avro CF 105 "Arrow", a 30-ton supersonic delta-winged interceptor designed by Avro Aircraft Limited, Malton, Canada.

Residual stresses whose magnitude and directionality are not precisely known can have a marked effect on the integrity of a component in the aircraft structure, and, during manufacture of the components, may cause distortion and increase greatly the cost of producing parts to close tolerances. Metallurgically, residual stresses may influence the fatigue life of components and can be one of the causes of stress-corrosion failures. Control of the residual stresses is, therefore, of extreme importance. The effective and widespread use of 7075-T 6 heavy plate in the stretcher-leveled, stress-relieved condition for integrally stiffened wing skins shows the extent to which the above points have been appreciated but, until recently, it was not feasible to apply this means of stress relief to forgings. Figure 1 illustrates what actually occurs under practical conditions of stress-relief by plastic deformation.

In a component there may be two stress-strain curves (Fig. 1, bottom) of identical slope and shape. One starts above the origin on the ordinate, denoting a residual tensile stress; the other starts below the origin, indicating a residual compressive stress. As a load is applied to the component, the strain throughout the cross section is constant, but the strain to obtain equal permanent set

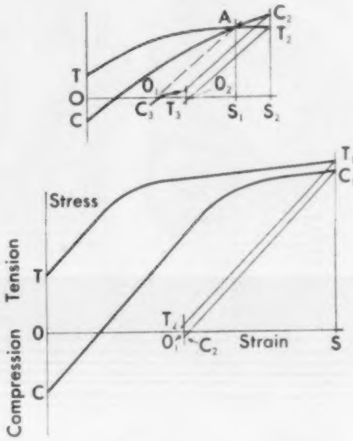

Fig. 1 — Stress-Strain Curves for Plastically Deformed Material

is not. When the yield point is exceeded throughout the cross section, a strain of T_1 and C_1 equal to the length of the line OS is achieved. When the component is unloaded, it recovers its elastic deformation such that the portion which originally had a residual tensile stress OT now contains a tensile stress of O_1T_2 and the portion of the component originally in a state of compression OC now contains a compressive stress of O_1C_2, the original total residual stress TC having been reduced to T_2C_2.

In nonhomogeneous material of different moduli in tension and compression, the set of curves in Fig. 1, top, illustrates the action. If exactly the right amount of strain is applied, the residual stress can be entirely eliminated, but if too much strain is applied, a tensile residual stress will be developed.

The degree of compressive deformation that must be applied to

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Stress-Relief . . .

achieve the desired relief of residual stress can be calculated from the compressive curves obtained on the material in the heat treated condition in which it will be used in practice.

To check the effectiveness of the stress-relief on the X 7079-T 65 hand forgings, residual stress determinations were carried out using the method of Rosenthal and Norton. Strain gages were applied to the outer faces of a fairly large hand forging, which was then split; gage readings were recorded, and then further gage readings were taken as the metal was milled away in 0.50-in. increments. Two such tests were carried out, one on a stress-relieved forging, the other on a forging which had not been stress-relieved. For the latter condition, the residual stress in the 7075 material was found to be within the range 30,000 to 35,000 psi. and for X7079 20,000 to 25,000 psi. For the X 7079 material in the stress-relieved condition, the figure was about 5000 psi.

W. A. Morgan

Freezing of Continuous Castings

Digest of "Solidification Characteristics of Continuously Cast Low-Carbon Steels", by M. Tenenbaum, C. F. Schrader and L. Mair, *Journal of the Iron and Steel Institute*, Vol. 191, January 1959, p. 20-33.

Inland steel co. has investigated the continuous casting of carbon steels containing less than 0.10% carbon. Work was done at the Atlas Steels Ltd. plant. Of the 35 heats of steel (varying from 6 to 30 tons) which were cast, this paper discusses the results obtained with 12 representative heats.

A much higher ingot yield is obtained from semikilled and rimming than is possible from killed steel. The latter type produces a sounder ingot; however, it contains more surface flaws along with a shrinkage cavity which usually causes about a 10% lower ingot yield. Inland Steel was interested in determining whether ingot yields on killed steels equal to ingot yields on rimming

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Continuous Casting . . .

steel could be obtained by continuous casting.

Of the 12 heats described in this article, eight were made of the full rimming type with additions of only about 0.60 lb. of aluminum added to control the rimming action. One heat was partially deoxidized with 0.07% silicon, one totally deoxidized with 0.033% aluminum, one totally deoxidized with 1.70% silicon, and one totally deoxidized with 0.035% vanadium. The heat with 0.07% silicon would normally be termed a semikilled heat, while the other three would be almost totally deoxidized.

The last four heats, with varying degrees of deoxidation, all seemed to cast in a similar manner, and yielded a very dense slab as far as structure was concerned. The slab molds were 24 × 6½ in. and 20 ft. long. Withdrawal rates through the mold varied from 35 to 60 in. per min., and ingots were 26 ft. long before cutting. These deoxidized heats shrink away from the mold wall; this apparently caused a slower rate of cooling because of the insulating effect of the air gap. As a result, most of the deoxidized heats, which apparently contained no gas at all, solidified in massive dendrites growing out from the mold wall and meeting in the center of the section. Some even showed corner cracks, which is typical of this ingotism.

In the rimming steel casts, a wide variety of blow hole structure developed in the mold cross section. Most of these steels had a dense carbon-free surface zone and an inner zone containing blow holes and sulphur segregation. There was little segregation of any other element. Blow hole distribution was profoundly affected by the amount of aluminum added per ton and also by the casting rate in in. per min. For example, on one heat to which was added 0.35% aluminum, the blow holes were very deep-seated, at least 2 in. from the surface of the slab. With 0.55% aluminum, the blow holes were evenly distributed across the whole cross section of the slab. In a like manner, a steel which was cast at a rate of only 26 in. per min. showed a dense structure free of blow holes for about 2 in. and then large blow holes in the center of the

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Continuous Casting . . .

ingot. Another section from the same heat, which was cast at a rate of 40 in. per min., again showed blow holes over the whole cross section of the ingot. This would indicate that too much aluminum or too fast a casting rate would yield an undesirable blow hole distribution since blow holes might appear right under the ingot skin.

Segregation studies of both the rimmed and killed steel cross sections showed that sulphur at the outer rim surface of the ingot was 0.025% and about 0.042% in the center half of the ingot. There was no segregation of carbon in either the rimmed or killed steel.

E. C. WRIGHT

Arc Welding . . .

(Continued from page 124)

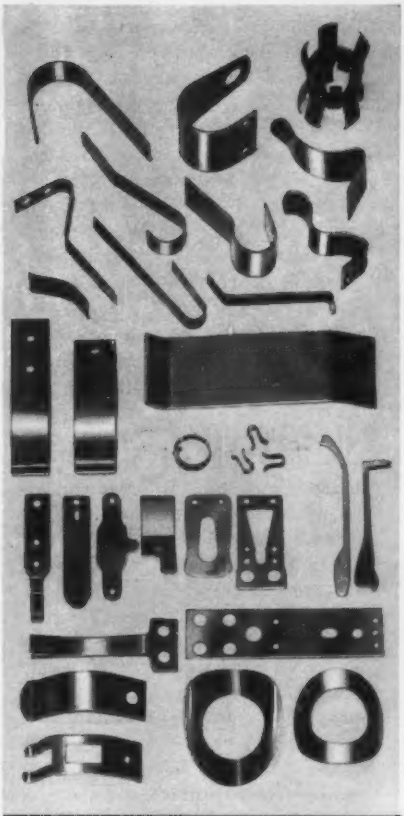
reactors may be needed unless the proper internal inductance has been provided in the power supply. Wire diameters of 0.045 in. or less are preferred. Sections less than ⅛ in. thick, for example, require electrodes 0.035 in. diameter.

To handle the small wire diameters, new welding guns were developed. Most early equipment pushed wire to the gun through a casing as long as 20 ft. Very fine wire buckled, creating feeding problems which were resolved by pulling wire through the casing with drive rolls contained within the gun body. A typical gun designed for feeding fine wire is shown in Fig. 2 on p. 124.

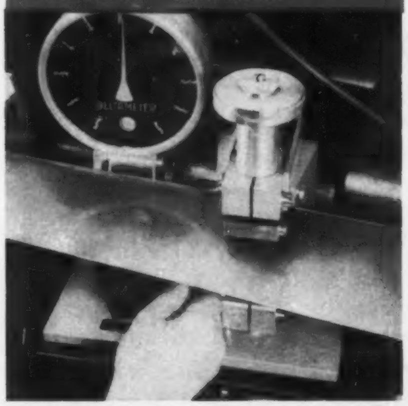
Experience has shown that somewhat less operator skill is needed if the length of electrode extending from the gun tip is held below ½ in. Short extensions result in higher transfer frequency with less spatter and permit a wide range of electrode feed rate without adjustments in the power supply output. More manipulation of the arc with good stability of metal transfer is also possible.

Welds Mild Steel

By combining all of the elements of power supply design, low arc voltages, small wire diameter, and short extension, mild steels can be welded with ease using carbon dioxide shields. The arc generates a



Strip thickness is checked during rolling and at final inspection with a "Deltameter", an instrument developed at Sandviken for measuring variations of thousandths of a millimetre.



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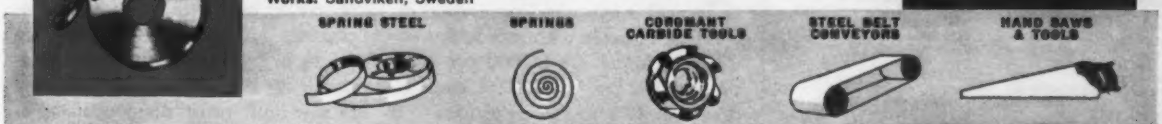


SS-200

Circle 920 on Page 48-A

Arc Welding . . .

characteristic buzzing noise which indicates to the welder that his settings are proper. Very little skill is needed on the part of the welder to produce sound, well-formed and spatter-free welds. This is particularly true when compared to the training needed to develop a welder who will be competent with covered electrodes in out-of-position welding.

Fillet and butt welds can be made with the Dip-Transfer method in sections as thin as 16 gage. A vertical fillet weld made in 1/16-in. sheet is shown in Fig. 3 (p. 124). Welds shown are in the as-welded condition; the slag and spatter produced by welding have not been removed. Such joints can be welded in all positions. Heavier sections also may be welded since deposition rates as high as 6 lb. per hr. have been achieved in welding vertical joints using small-diameter electrodes with an average current of up to 200 amp. Welds made with the Dip-Transfer method are sound, and spatter losses are less than 5%.

Some slag is formed by oxidation of manganese and silicon from the electrode. About 30% of the original amount of these elements is lost. When welding mild steels, oxidation losses are not a problem. However, the mechanical properties of welds in low-alloy steels may suffer because of losses of critical elements. More of these elements are retained by substituting mixtures of argon and carbon dioxide for pure carbon dioxide.

Figure 4 on p. 124 shows a butt weld made in ½-in. plate positioned vertically. This weld was made with the Dip-Transfer method in a shield of 80% argon and 20% carbon dioxide. Three passes were used and the arc was oscillated across the joint to form a wider deposit. Weaving was not necessary to keep the pool from running out. The weld shown has not been cleaned; the small amount of slag and spatter is typical of that formed with Dip-Transfer in pure carbon dioxide as well as the argon and carbon dioxide mixtures.

Typical mechanical properties of weld metal made with standard mild steel electrodes are 83,000 psi. tensile, 66,000 psi. yield, 19% elongation, and 47% reduction in area.

The Dip-Transfer method probably will find most use in the fabrication of sheet and thin plate since welding of such thicknesses is particularly difficult at this time. Heavy sections are easily welded in the flat position with existing processes; Dip-Transfer will have a particular advantage in vertical or overhead applications. Even with Dip-Transfer, however, relatively high currents are necessary to achieve adequate fusion in heavy sections. As a result the molten tip becomes more globular and the weld pool more fluid. Careful control must be exercised so that the weld pool will not be lost.

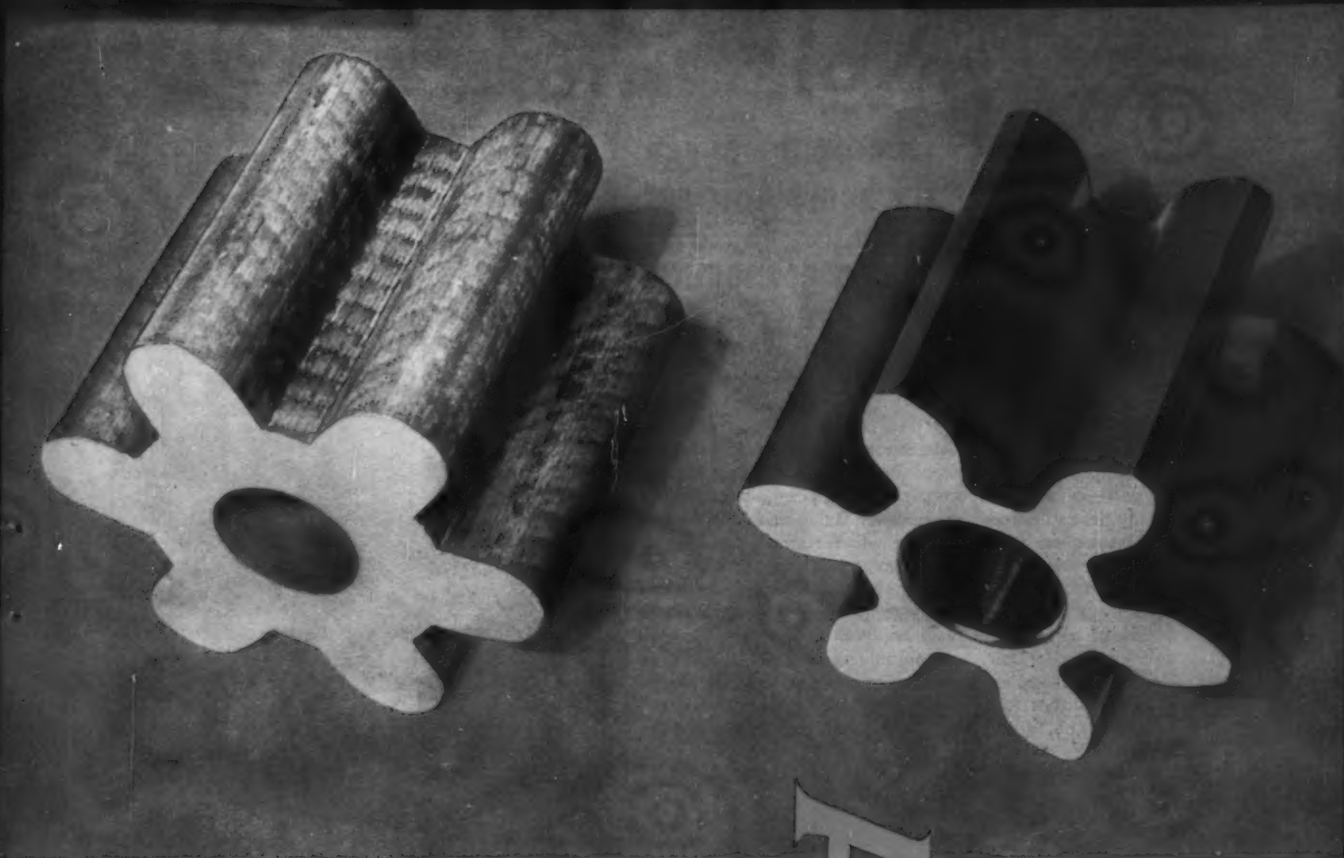
Large-diameter wires may be used with the Dip-Transfer method to improve control of welding, but are not recommended in general. Wires of small diameter (0.045 in. and less) can be used at low currents to gain the greatest advantages. Even at these low currents, however, the rate of deposition of weld metal can approach that possible with larger diameters and higher currents since resistance heating is more effective in melting electrodes of smaller wire.

The Dip-Transfer method will probably find its greatest use in the fabrication of mild steel components. It is here that economics plays the greatest role and that the greatest need is found. However, other metals and alloys can be welded by Dip-Transfer, and inert gases or mixtures of argon and carbon dioxide may be substituted for carbon dioxide, if needed. As an example, aluminum has been welded successfully in an argon shield with a 0.030-in. diameter electrode.

Porosity of Plated Coatings

Digest of "Porosity of Plated Coatings", Technical Report STR-2389, National Bureau of Standards, Washington, D. C.

Pores and other flaws reduce the protective value of electroplated coatings on metals. The National Bureau of Standards has been studying physical and chemical methods of detecting pores, and the influence of gas on pore formation. Flawless coatings are particularly important in such high-temperature applications as jet engines because the metals must resist sharp changes in environment. *(Cont'd on p. 164)*



Circle 921 on Page 48-A

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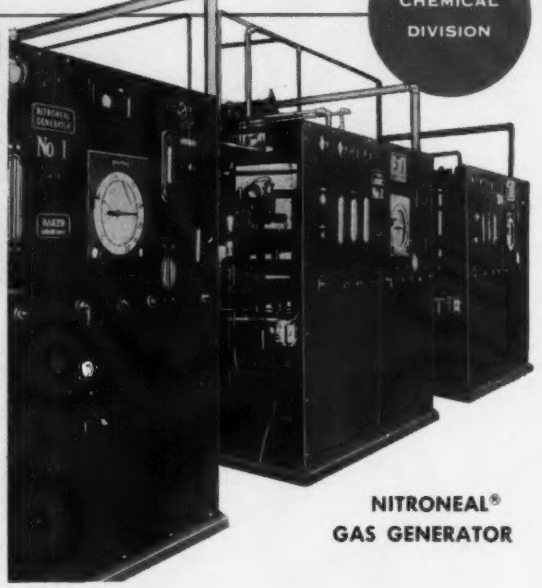

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Circle 922 on Page 48-A

Porosity . . .

Although much research has been directed toward pore detection and elimination, methods of examining pores on metallic coatings with the microscope have received little attention because most pores have diameters too small for adequate sectioning. Parallel sectioning is a technique which involves polishing off some of the coating perpendicular to the axis of the pore and parallel to the basis metal. When the cut section is studied under a microscope, the pore will appear as a small dot which can easily be seen at a magnification of 400 if the pore is larger than 0.05 mil in diameter.

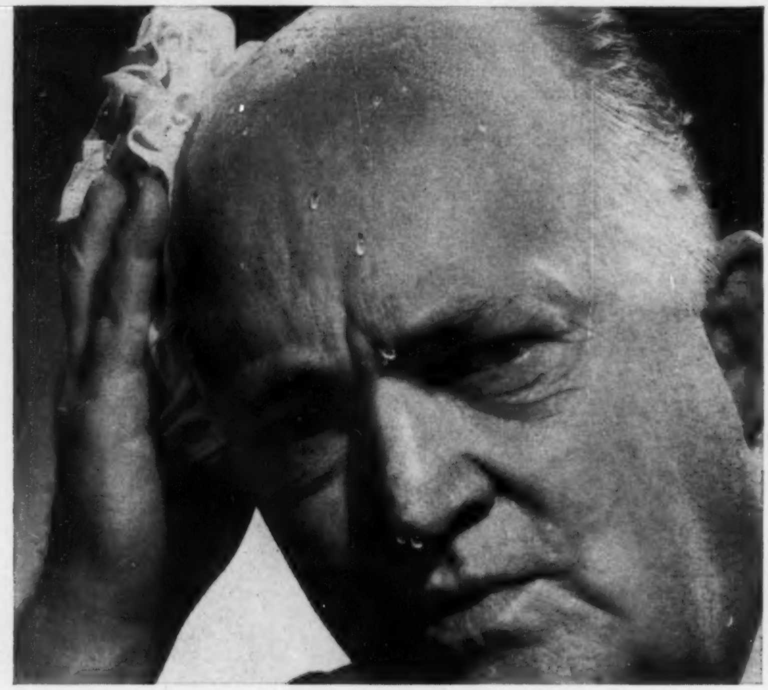
Locating Pores – To make sure the dot is not a surface defect introduced during polishing, successive layers are removed and examined until the underlying metal is reached. If the dot is a pore, it will reappear consistently at the same spot. A pantograph arrangement is used to relocate the exact position of the pore after successive removal of each layer. With this technique, the size and shape of pores or other defects which are difficult to cross section can be determined and the damaging effects of atmospheric corrosion can be studied. Four types of pore defects were found in these microscope studies: pits (dead-end pores), cavities (enclosed pores), continuous pores, and bridged-over pores.

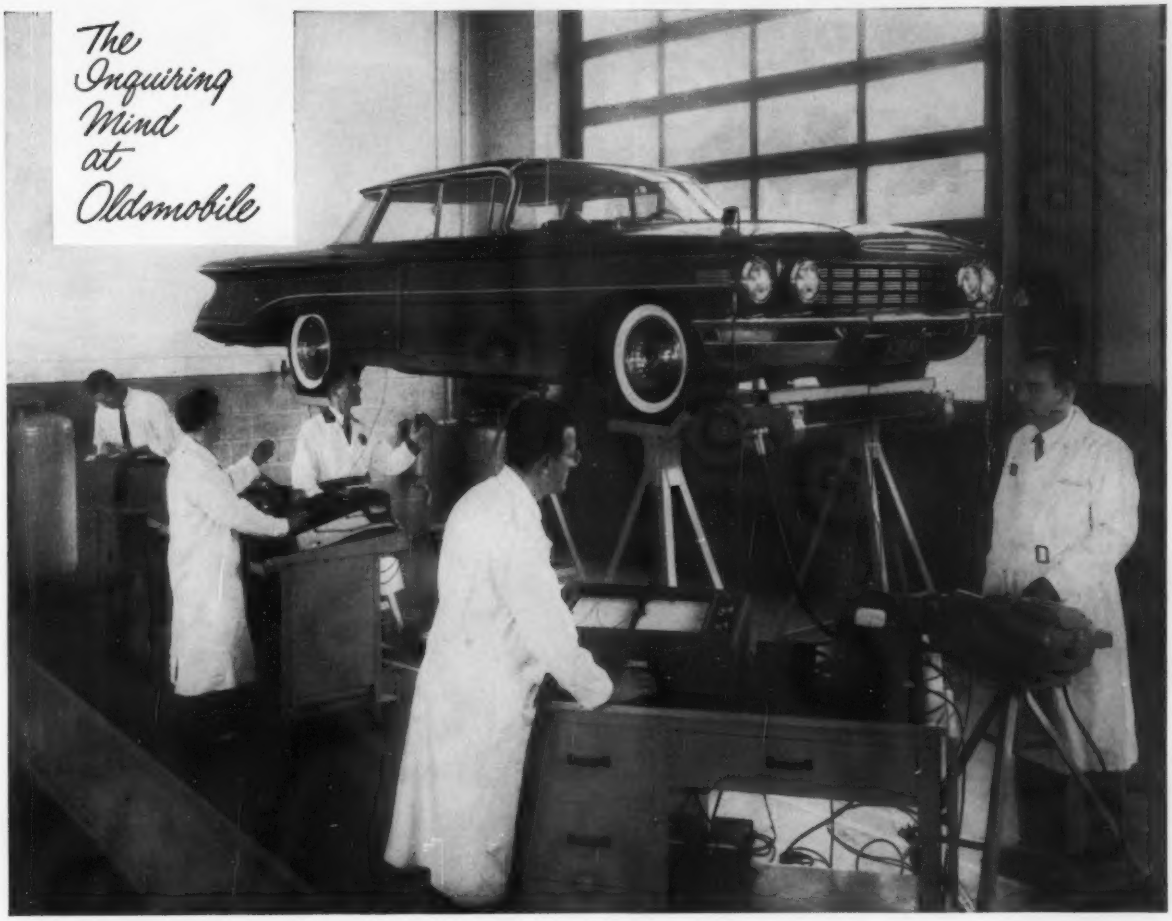
Ferroxyl Test – Perhaps the best known porosity test for nickel coatings on steel is the ferroxyl test. Experiments were conducted which showed that the sensitivity of the ferroxyl test decreased as the pore size decreased. Virtually all pores 0.5 mil or more in diameter were detected by the ferroxyl test while very few pores less than 0.1 mil in diameter were detected. Since smaller pores are more numerous than larger ones, it is evident that the ferroxyl test has rather severe limitations.

Influence of Gas – Several factors may initiate pores: inclusions in the basis metal, surface contours and other discontinuities of the basis metal, foreign matter in the bath that settles on the cathode, and sites of nucleation on the basis metal which build up without filling all intervening spaces. No matter which of these initiates a pore, once it has been started, subsequent deposition should bridge over it. The fact that this bridging over does not always continue with deposit build-up may be explained by gas discharge or bubble formation. From studies using parallel sectioning techniques, it seems likely that almost all pores follow the normal tendency to bridge over; those that are prevented from closing up due to gas accumulation cause porosity.

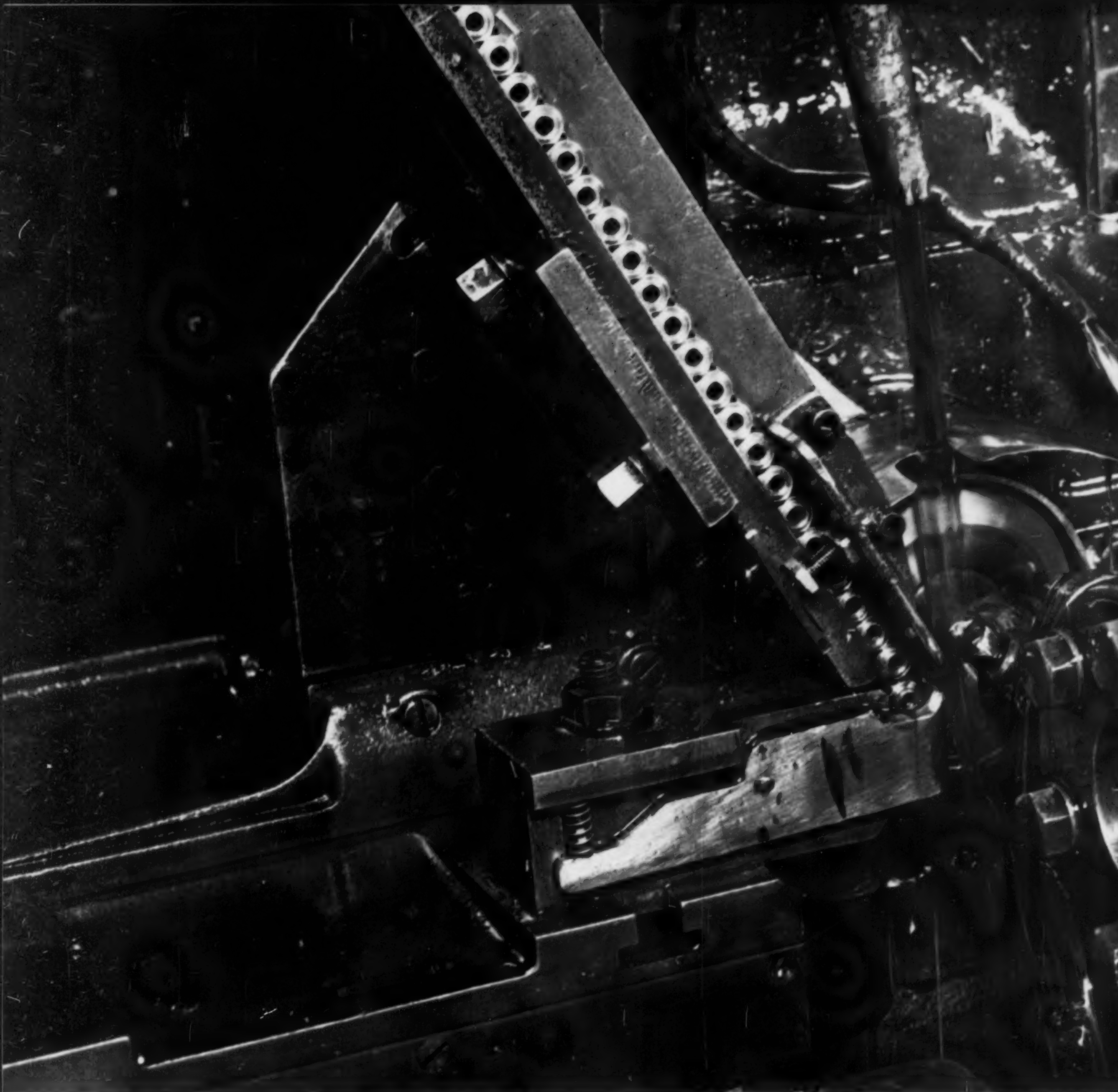
One factor contributing to the formation of pores involves the growth of a deposit around a gas bubble. To study the effect of gas on porosity, a cell was developed with a transparent bottom so metal deposition could be observed. This cell has a concentric cylindrical electrode system so that the cathode (the metal being plated) is at the center of the system, pressed down on the thin cell bottom.

Hydrogen Studied – Deposition around the periphery of the cathode





Circle 924 on Page 48-A



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Circle 927 on Page 48-A

Porosity . . .

can be observed through this transparent bottom. When the current density is increased until hydrogen evolves, and then decreased slightly, hydrogen bubbles remain attached to the plated surface. If the cell is operated at a low current density, the deposit thickens at a uniform rate with few visible defects. At high current densities, hydrogen, evolved in great excess, produces a rough deposit which has very poor adherence.

The relative rates of hydrogen discharge and metal deposition were found to determine whether a bubble is covered over by the deposit or enlarges itself. When a gas bubble is large enough to break away from the deposit, it leaves some gas in the pore formed by the deposit growing around the bubble. This gas keeps the electrolyte from entering the pore and so prevents the deposit from forming across the pore opening. Although this experimental procedure differs from actual industrial conditions in several ways, observations indicate that the pore growth mechanism it demonstrates is applicable on a broader scale.

A. G. G.

Radio-Isotopes . . .

(Continued from p. 101)

In the ferrous field, there are good data for the study of slag-metal reactions, erosion of refractory linings in blast furnaces, metal cutting with high speed and carbide tools, malleabilization of white iron, and zone melting. For example, work at the Franklin Institute has advanced zone-melting techniques to where they can handle 1-in. cross sections of iron, and the Spring Garden Institute's and Leeds and Northrup's scientists have accumulated a wealth of information on economical removal of hard and tough metal with automatic machines.

In the nonferrous field, the solid-state physicist has derived much information on atomic diffusion within metals, on the purification by zone-melting of titanium, zirconium and molybdenum, the relation of substructures to crystal orientation and the influence on mechanical properties, accurate measurement of trace

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Also used for brazing panels for the B-58 Hustler, the big furnace is but one of many special furnaces that Pacific has designed and built to provide faster, more efficient production of stainless steel honeycomb. If your requirements call for a special furnace such as this or a standard design furnace, Pacific can be of service to you. For specific information call or write Pacific Scientific Company today!

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- **Brazing temperature 1650°F.**
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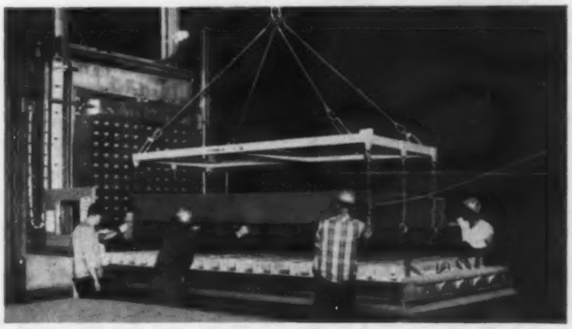

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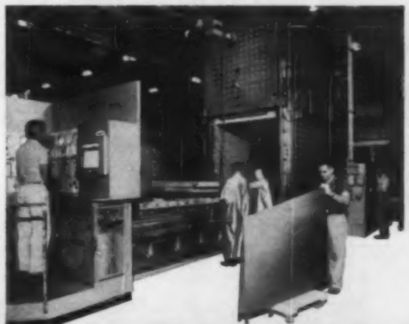

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Circle 929 on Page 48-A

Radio-Isotopes . . .

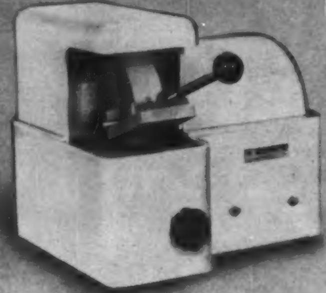
elements and their effect on the mechanical and physical properties of metals at very low temperatures, and on the purification and improvement of fissionable fuels for nuclear reactors.

Mention might be made of special departments in important research laboratories, such as Alcoa's at New Kensington, Pa. Much of their work uses a relatively short-lived isotope of aluminum, and complete arrangements are included for rapid shipment by air so as to cut down to a few hours the lapse between the time the metal is removed from an A.E.C. reactor to the time it arrives at the investigator's door.

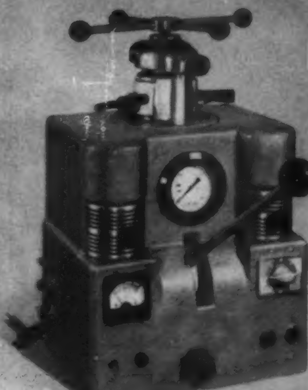
Research data from laboratory studies with the help of radioisotopes infrequently result in daily use in production practices (the β-gage is an important exception) but they offer unusual and unique opportunities for laboratory and pilot-plant evaluation of full-scale operations which will improve quality and lower cost.

Some of these potentialities appear to be the effect of alloying elements on thermo-electric properties of metals; discharges in vacuo, much as General Dynamic's new cesium diode plasma method for direct production of electricity from heat; flotation of heavy minerals as well as quartz; plastic deformation in hot and cold working and lubricants to facilitate these operations; improved atmospheres for continuous bright annealing; the kinetics of precipitation hardening; control of gaseous and nonmetallic segregations in cast alloys; machining of refractory special-purpose alloys; improvement of the metallurgical bond in clad products or bimetals; electrolytic co-deposition of metals; improvements in metallic and ferritic magnets; study of lattice imperfections in crystals and aggregates and their relation to fatigue and inferior performance under load at elevated temperatures; control of metal deposition during welding; determination of flaws in fabricated containers for solid rocket fuels; and the kinetics of recovery, recrystallation and grain growth.

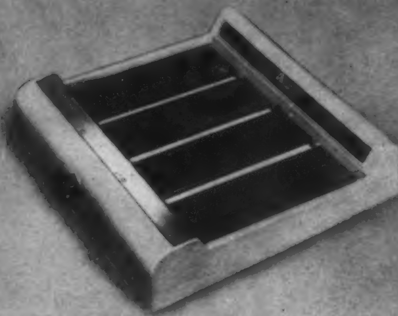
Truly this is an impressive list. The protective blanket of "patents pending" conceals much detailed



1114 AB Cutter



1330 AB Speed Press



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1720 AB Electro-Polisher

Circle 931 on Page 48-A

Radio-Isotopes . . .

information today, and technical publications in the immediate future will not emphasize much actual technology. The metallurgist must dig for himself. His work will not be unduly difficult, and the Office of Isotope Development of the Atomic Energy Commission is ready to assist him in many ways.

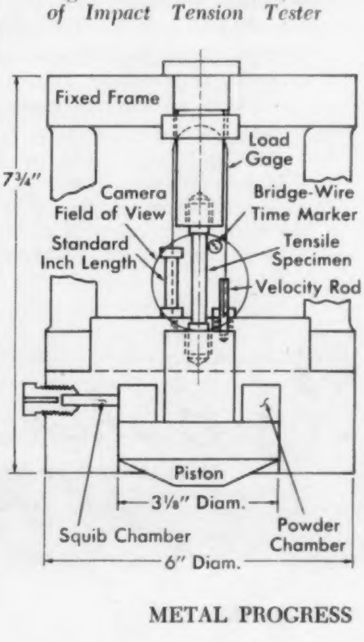
Tensile Properties at High Strain Rates

Digest of "The Tensile Properties of Some Engineering Materials at High Rates of Strain", by A. L. Austin and R. F. Steidel, Jr., A.S.T.M. Preprint No. 81. Paper presented at the 62nd Annual Meeting of the American Society for Testing Materials, June 1959.

PREVIOUS INVESTIGATIONS have shown that the dynamic strength of most materials increases with increasing strain rate. However, no accurate measurements have been made at very high rates of strain. The authors describe the use of an explosive-impact tester which can measure accurately, and simultaneously the rate of change of diameter and load for tests on a standard 1-in. tension specimen. A diagram of the equipment is shown in Fig. 1.

The diameter changes are meas-

Fig. 1 – Schematic Diagram of Impact Tension Tester



Tensile Properties . . .

ured by a high-speed framing camera, and load is measured by two strain gages mounted diametrically opposite on the load cell. The gages are connected in series into a standard Wheatstone bridge circuit, and the output of the bridge amplifier is fed into an oscilloscope. As the specimen necks, instantaneous strain rates as high as 25,000 in. per in. per sec. are accurately measured over time intervals as short as 5.9 micro-sec. This is 100 times shorter than the rates achieved by previous investigations. The paper gives a detailed account and diagram of the complex electronic circuit necessary to synchronize the camera exposures and load measurement.

The results of tests on S.A.E. 1018 cold rolled steel and 6061-T 6 aluminum alloy show that the fracture strengths increase continuously with increasing strain rate up to 24,000 in. per in. per sec. Measurements of reduction in area and elongation indicate that the ductility of these materials approaches a constant value with increasing strain rate. Figure 2 shows the form of the curve typical of these two materials. The

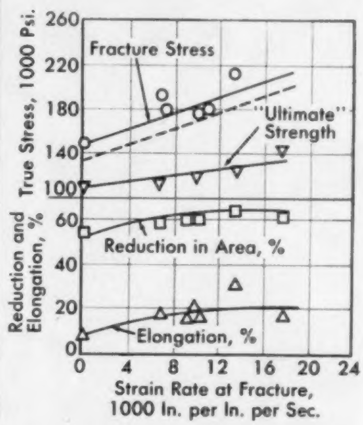
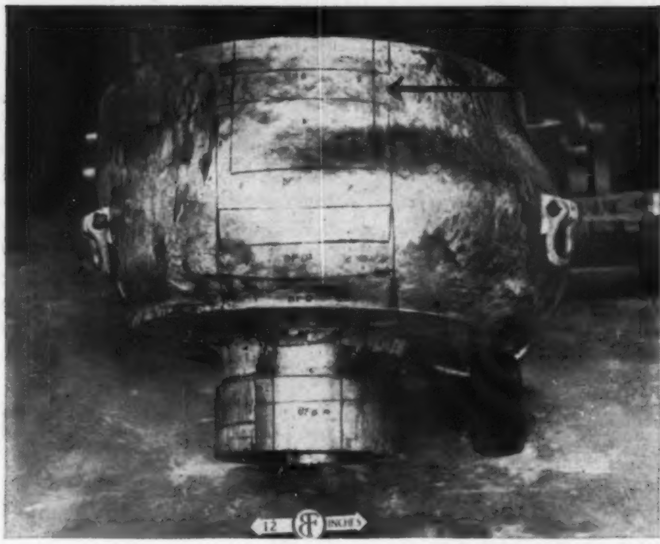


Fig. 2 – Explosive-Impact Tension Tests at Room Temperature. Material is cold rolled 1018; dashed line is corrected curve

dashed line in the graph is the corrected fracture-stress curve, derived from a correction factor calculated by Bridgman. The amount of correction remains constant with strain rate and is about 10% for steel and 14% for the aluminum alloy.

As Fig. 3 shows, the fracture stress



Marks on the casting show positions of the films during exposure. Above, radiograph of the area indicated.

5 tons of stainless casting... Radiography goes over it inch by inch

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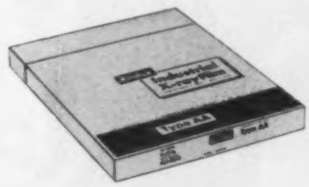

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Circle 935 on Page 48-A

Tensile Properties . . .

of A 110-AT titanium alloy is at a minimum 11,000 per sec., and then continuously increases. Ultimate strength rises to a maximum, and is nearly equal to the fracture stress. At this point, also, the ductility is at a minimum. For the C 120-AV alloy, the fracture stress and ultimate strength follow the same trend as that for the A 110-AT alloy, but the ductility does not reach a minimum.

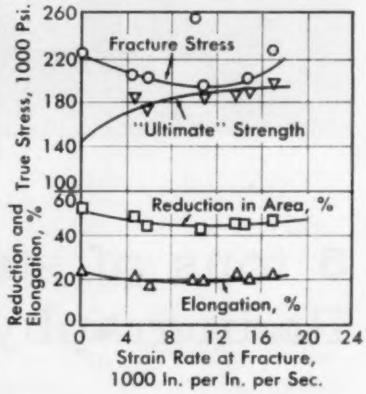

Fig. 3 – Explosive-Impact Tension Tests on A 110-AT Titanium Alloy at Room Temperature

The reduction in area increases continuously with strain rate, and the elongation remains constant.

From the results reported by the authors, it is evident that the dynamic behavior of materials cannot be predicted from static tension tests alone. The explosive impact tester does however provide a way to obtain an intelligent comparison of materials for use in a particular dynamic application even though it may not simulate actual conditions.

W. A. MORGAN

"Clean" Steels

Digest of "Effect of Melt Shop Practice on Cleanliness for High Speed Steels", by W. L. Havekotte. Paper presented at the A.I.M.E. Electric Furnace Conference, Cleveland, December 1959.

THIS is primarily a discussion of the author's experience with the H-F (harden and fracture) test as applied to high speed steels and especially of the factors which affect the forma-

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Richard Juetten, Supervisor of Salt River's Pump Division, reports that the use of La Salle FATIGUE-PROOF steel bars has permitted a saving of $699.00 per pump . . . a potential saving of $174,750 when applied to the 250 pumps now in operation.

Mr. Juetten's report follows:

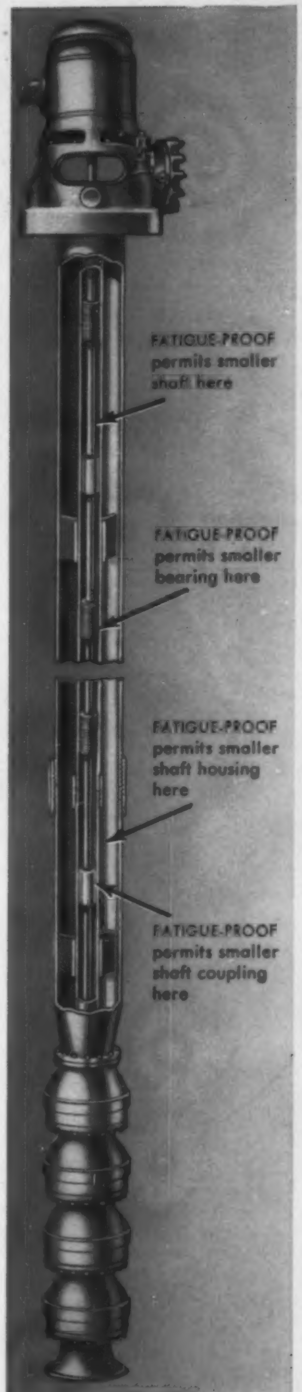
"I have figured our direct saving realized by using La Salle FATIGUE-PROOF steel bars in place of standard C-1045 steel shaft in our deep well turbine pumps.

"FATIGUE-PROOF enables us to use bars only $1\frac{11}{16}$" in diameter . . . instead of $2\frac{3}{16}$" diameter shafts which were necessary when we used C-1045 . . . and this despite higher horsepower, more weight, and additional pump bowl assemblies.

"Here are comparative costs per 10-foot section (of a 300-foot pump shaft):"

using C-1045		using FATIGUE-PROOF	
10' x 2-3/16" dia. shaft	$28.30	10' x 1-11/16" dia. FATIGUE-PROOF	$22.59
3½" shaft housing	26.30	3" shaft housing	19.80
2 bearings, 3½" x 2-3/16"	21.72	2 bearings, 3" x 1-11/16"	13.46
Shaft coupling	5.16	Shaft coupling	2.34
TOTAL cost	$81.48	TOTAL cost	$58.19
Cost per foot	$ 8.15	Cost per foot reduced to	$ 5.82

RESULT: A saving of $2.33 per foot . . . or $699.00 when applied to a 300-foot pump setting. And this doesn't take into consideration reduced power consumption.



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Circle 937 on Page 48-A

"Clean" Steels . . .

tion of visible failures which occur in specimens fractured by transverse impact loading. These failures, which are visible at very low magnification, are called "slits". They are related to the nonmetallic stringers which have been extended on hot working so they are parallel to the axis of the hot rolled bar.

This paper is very well written and great care has been used to show the results of a large number of tests, and how the number of "slits" seems to be related to temperature, silica in the slag, slag mixture with metal as tapped, and other factors. However, little data has been given on some of the factors which affect the silicate content of the bath as tapped or on the inclusions which have an important effect on the transverse impact properties. One of the first steps forward in improving the cleanliness of steel was the early introduction, many years ago, of excess manganese to form fusible manganese silicate with the SiO_2 about as fast as it was formed. When the temperature and action were right, the manganese silicates were easily carried to the slag. Where cleanliness was an important requirement, manganese was especially added early for this purpose.

In Mr. Havekotte's paper, no reference is made to manganese added early to remove silicates. It would be interesting to get this data into his paper. Silicates are rapidly formed at temperatures below 2700° F. and the manganese has to be in solution on meltdown and present as MnO to form manganese silicates as fast as it contacts the silicates.

Also, little is said about the sulphide types, and, in fact, nothing is said about the sulphur content. Here, the type of sulphide is much more important than the amount of sulphide, especially in the as-cast ingot structures. The adverse effects of sulphides on hot and cold impact values are much more directly related to the type of sulphide than the amount. The Type II sulphide, which is a primary cause of hot shortness and low transverse impact values, is apparently only formed in heats where the deoxidation has been carried to extremely low limits by strong deoxidizers such as aluminum. Under the right conditions of deoxidation and solidification, traces of Type II sulphides can be found even when the total sulphur content is under 0.020%.

It would be interesting if Mr. Havekotte could check the manganese addition practice as well as the deoxidation and sulphur practices of the heats of high speed steel which he has covered in his paper and indicate the possible relation to "slit" formation.

H. W. McQuaid

Automatic Welding

Digest of "Problems in Welding Automation", Reports of Institutes of Higher Learning—Machine-building (Russian), No. 1, 1958.

The basic welding method in the U.S.S.R. is submerged arc welding. In heavy machine building, for example, 30% of all welded construction is accomplished by this method. In general, it is used for joining carbon and low-alloy constructional steels up to 2 in. thick in long, straight, and circumferential joints. All storage tanks are welded by submerged arc in a shop, rolled up for transportation, and then erected on site (see *Metal Progress*, November 1959, p. 107).

Spiral welded gas line pipe is manufactured in an automatic line at the Zhdanov Works. Submerged arc welding is also used for joining 18 Cr, 9 Ni austenitic steel with

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SCIENCE

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Circle 940 on Page 48-A

Automatic Welding . . .

various titanium, vanadium and other additions, as well as aluminum and certain titanium alloys. The use of several electrodes with three-phase arc and separate current sources, split electrodes located along and across the joint (for variable clearances) are some of the recent innovations.

Electroslag welding (see *Metal Progress*, January and November 1959) is used for vertical joints, without preparation. Its economy increases with thickness – 8 to 16 in. is common – and parts up to 50 in. have been joined. Thick-walled pressure vessels, press frames, large diameter solid and hollow shafts of low-carbon and austenitic steel have been welded by this method.

Both consumable and nonconsumable argon-arc welding are used for joining low-allow and austenitic steels, as well as aluminum, copper and titanium alloys. In welding austenitic steels, the concentrated nature of the consumable arc aids in retaining corrosion resistance. Tungsten argon arc is used to lesser extent than consumable, mainly for joining austenitic steels and other alloys.

Carbon dioxide welding has been used as a substitute for argon arc for economic reasons. Automatic and semi-automatic in carbon dioxide atmosphere is used for welding very small thicknesses, such as in butt, corner, lap, and T joints. Due to deep penetration, it is possible to weld, without preparation, 18 Cr, 9 Ni, and 18 Cr, 9 Ni plus Ti austenitic steels, CrMo heat resistant steels (with joint retaining high mechanical properties after aging at 950 to 1000° F.), and low-alloy high-constructional steels. Plates up to 2½ in. have been welded in CO_2. For joints with small joint bevel angles, automatic welding in CO_2 is more economical than submerged arc.

In general, argon arc is used primarily for more costly materials: aluminum, magnesium, corrosion resistant, austenitic, heat resistant, titanium, and the like. CO_2 is used for low-carbon and low-alloy steels.

Development of high-production welding methods, especially in inert atmospheres, creates additional requirements for energy sources. These requirements are satisfied by stable arc characteristics and small

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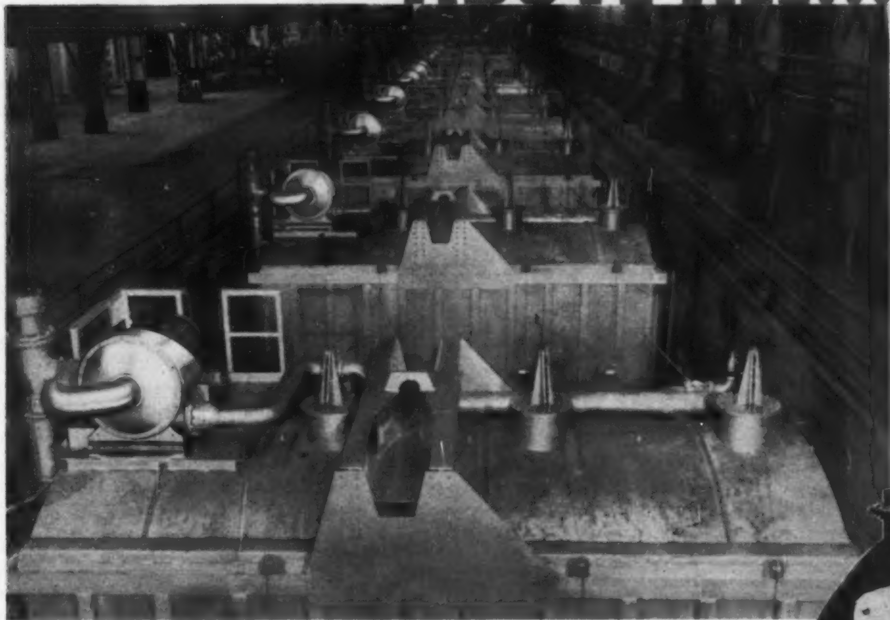

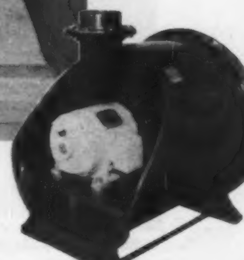

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Circle 941 on Page 48-A

Automatic Welding . . .

electromagnetic lags. New welding wire types for arc stabilization, CO_2 welding with alternate current and development of rectifiers for d-c. welding are current problems.

A semi-automatic consumable arc welder for short butt, corner, and lap joints, pipe bends, and tack welding parts in all positions is available. Wire is fed by a 27 w. motor at 27 v., the d-c. welder weighs about 3 lb.

Other automatic installations for welding carbon and alloy steels in protective atmospheres, with or without backups, use wire for butt, circumferential and T-joints, at rates from 80 to 460 ft. per hr. Corrosion tests have shown that the consumable electrode argon-arc joints are more resistant to intercrystalline and general corrosion than manual arc joints.

Tungsten arc welders for pipe have been developed. Welding speed is somewhat lower than that of the consumable wire method, but better penetration is achieved. A machine for butt welding 28-in. diameter pipe has been developed and is being used experimentally; it uses CO_2 atmosphere and direct current. Machines for welding bend joints in low-carbon and austenitic steel pipe under protective atmospheres, without backing rings, are currently under development.

More economic application of argon and CO_2 is under investigation. Programed welding and mechanization of auxiliary operations is being developed. These problems are being studied at the Bauman Technical Institute in Moscow, where equipment here described was developed. ARTHUR B. TESMEN

(More digests on page 190)

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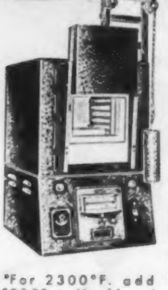

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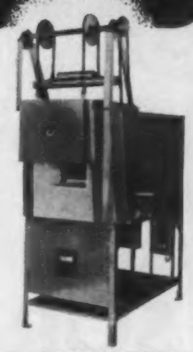

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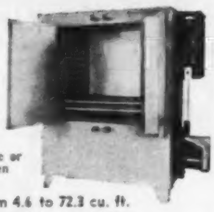

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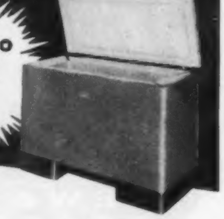

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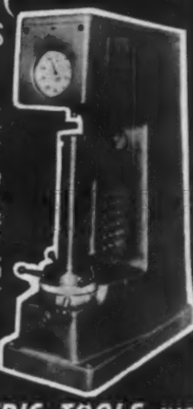

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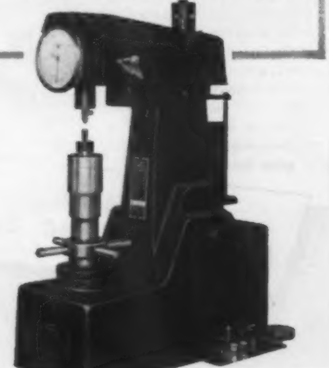

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Welding Light Alloys

Digest of "Gas Porosity and Sources of Hydrogen in the Metal-Arc Welding of Light Alloys", by W. G. Hull and D. F. Adams, *British Welding Journal*, June 1958, p. 282-290.

THERE IS RENEWED INTEREST in metal-arc welding of light alloys although the weld quality is still inferior to the argon-arc process. Previous workers concluded that porosity in metal-arc welds is due to hydrogen from free moisture in the coating; however, other sources are involved.

Commercial welds in H.10 (an aluminum alloy with 0.02% Cu, 1.14% Mg, 0.97% Si, 0.74% Mn and 0.28% Fe) show 3 to 5% voids. Melted ends of electrodes suggest that the core wire itself yields porous metal, which is transferred across the arc.

The factors investigated were free and combined moisture in coatings, hydrated oxide on core wire surfaces and internal hydrogen in core wires. Initially, two commercial electrodes with 10% silicon aluminum core wires were tested, a single pass butt weld being deposited under standardized conditions. The percentage voids in each weld were estimated by comparing the weld density with that of a microscopically sound ingot of identical composition.

Free moisture in coatings was determined, and was 0.28 and 0.4% in the two brands tested. Drying at 110 to 300° C. (230 to 575° F.) reduced these figures to 0.01 to 0.2%. Subsequent exposure to the atmosphere at 72 to 79% humidity for 24 hr. led to moisture contents of 0.4 to 2.3%. The free moisture fell during welding to 10 to 30% of the initial value. About 0.5% water of crystallization was present in both brands. This was stable at 300° C. (575° F.) and to welding heat, as shown by stub ends. Internal core wire hydrogen was mainly in the range 0.5 to 0.9 ml. per 100 g. The surface corrosion product on core wires gave hydrogen contents of 2 to 5½ ml. per 100 g., unaffected by drying but exhibiting big variations.

Welding tests on two electrode brands indicated no correlation between free moisture and porosity, all welds containing 2½ to 3½% voids, even from electrodes still hot

Welding Light Alloys . . .

from baking at 300° C. (575° F.). This indicates the importance of other sources of hydrogen.

Experimental electrodes were made, using 10% silicon aluminum core wires to assess these sources. Welding tests were performed by the self-adjusting arc process, using a short arc at below the threshold, to give the globular transfer characteristic of metal-arc welding. To avoid damaging the electrode surface, the welding torch was modified so that a length of electrode was fed via a feed rod driven by the rolls. Thus, the electrode itself did not pass through the rolls.

Clean bare wire electrode deposits were exceptionally sound showing that internal hydrogen is insignificant. Corroded and stripped core wire electrode deposits exhibited 2 to 4% voids. Predried freshly coated electrodes containing only combined moisture gave deposits with 2 to 3% voids; undried freshly coated electrodes containing free and combined moisture gave higher values. This shows that corrosion products and combined and free moisture are important sources of hydrogen porosity.

Reduction of porosity involves elimination of free moisture by baking at 200 to 300° C. (400 to 575° F.) and elimination of coating constituents containing water of crystallization, stable at 300° C. (575° F.). Surface corrosion of core wire is minimized by using clean core wire and baking electrodes dry in manufacture, by storage under dry conditions, and by using unreactive coatings. Re-absorption of free moisture after baking is minimized by using hot electrodes or by moisture-free storage conditions.

P. D. BLAKE

Continuous Casting in England

A digest of "Continuous Casting at Barrow", by I. M. D. Halliday, *Journal*, Iron and Steel Institute, Vol. 191, February 1959, p. 121-161.

THIS DESCRIPTION of a continuous casting plant in England is confined to the casting of 2-in. square billets, although a few 3-in. square and 6 × 2-in. slabs were produced. The casting machine is about 46 ft. high. In operation, the small billet is extracted from the mold by pinch rolls. Guide rolls then turn the hot billet 90° to a horizontal position. The work described began in 1951, using the Rossi-Junghans type of equipment, and continued until the present date. Since many modifications of ladles, tundish, and molds were used, we shall only describe the final equipment.

In this investigation, a single strand and a double strand casting machine were used. The first molds were constructed of pure copper forgings, ¼ in. in wall thickness, with a copper flange on top. The mold was 32 in. long, surrounded by a steel casing which formed a 3/16-in. annulus up which cooling water was directed. About 140 gal. of water per min. (at 45 lb. pressure) was used to cool the mold, and the

Circle 956 on Page 48-A

Casting in England . . .

temperature increase of the water was about 20° F. About 3½ tons of steel were cast on the single-strand machine, and up to 8 tons on the double-strand machine. The rate of casting varied from 150 to 250 in. per min. on these small size billets.

A wide variety of steels were cast, with a range of 0.05 to 0.85% C. Silicomanganese and manganese molybdenum spring steels and two or three heats of 18-8 chromium nickel stainless were also cast. In the several years covered by these tests, 869 casts were made, mostly of 2-in. billets on both the single-strand and double-strand machine. Very high casting speeds could be attained on these small billets, as they cool so rapidly.

The final type of ladle used was a lip-pour type with a slag-retaining bridge positioned near the lip. The ladle was covered with a refractory cover and a combustion burner opener in the top was used for preheating the ladle to about 2700° F. This was necessary because the metal had to be tapped very hot from an electric furnace since it took about 2 hr. to pour 3½ tons of steel into these small billets.

The tundish was lined with fire brick and had a magnesia stopper, about 1 in. in diameter, in the bottom. Drawings and pictures are shown in detail of all the equipment used. Ladle tilting, mold filling and reciprocating, water flow, and several other details were controlled by electronic methods; this largely eliminated the personal element from the casting process.

E. C. Wright

Corrosion Testing Chromium-Plated Articles

Digest of "Accelerated Corrosion Testing of Chromium-Plated Articles — Sulphur Dioxide Tests", by J. Edwards, *Bulletin*, Institute of Metal Finishing, Vol. 7, No. 4, 1958, p. 55-78.

For many years, the most widely used accelerated corrosion test for evaluating chromium-plated articles has been the salt spray cabinet. Unfortunately, the results have only

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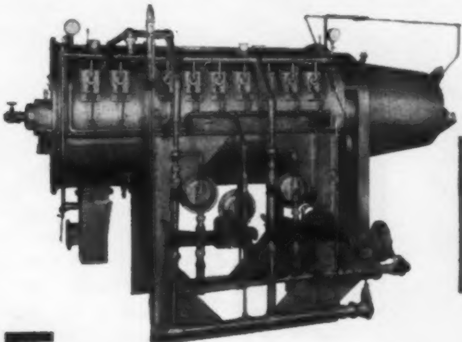

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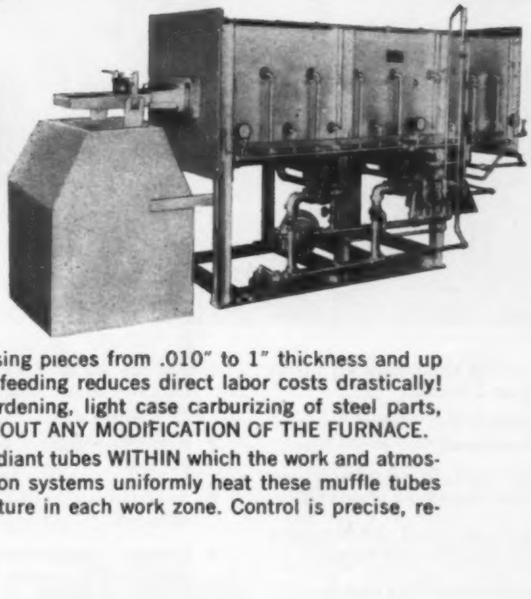

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Circle 958 on Page 48-A

Corrosion Testing . . .

been effective in disclosing porosity in the coating, and have not correlated with extended tests under actual atmosphere conditions. Fundamental studies disclose that the environmental corrosion mechanism involves the removal of a portion of the chromium, pitting, and localized corrosion of the underlying nickel coat prior to actual attack of the base metal. An accelerated corrosion test which more nearly accomplishes the same action, and which does correlate with actual environment corrosion tests, encompasses the use of an atmosphere of 1% sulphur dioxide, mixed with air saturated at least 95% with water.

Experimentally, the air and sulphur dioxide were premixed and bubbled continuously into the test chamber which contained a layer of water of measurable depth. A small fan mixed the atmosphere within the chamber. No heat was required to maintain the high humidity. Tests were run at 62 to 77° F. for periods of 24 and 96 hr. on segments of plated automotive wheel disks. Nine laboratories cooperated in the program to determine the degree of reproducibility and sample comparison.

Test results indicated that a 24-hr. test is inadequate if the total plating thickness exceeds 0.001 in. Tests lasted up to 96 hr. in preliminary work. Variations in sulphur dioxide concentration over an appreciable range did not alter the results.

Specimens exhibited pitting, cracking, flaking and general corrosion; these results closely paralleled those of field test experiments. Of the nine laboratories participating, six reported substantially identical results, while the remaining three found lesser corrosion rates. Subsequent evaluation tests of the three variant laboratories demonstrated either (*a*) abnormally low humidity, (*b*) lower temperature, or (*c*) severe cycling of temperature or humidity.

The author concludes that corrosion results obtained in this type of accelerated test are substantially identical to those experienced in long-time atmosphere corrosion tests. Results correlate much better than salt spray or other corrosion tests.

J. L. Wyatt

Titanium in Aircraft

Digest of "Titanium Fabrication and Reliability Problems in Aircraft", DMIC Memorandum 33, Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio.

Microstructure, reactivity and strength all affect formability and realiability of aircraft parts. The hexagonal close-packed (alpha) structure which unalloyed titanium has at room temperature changes to body-centered cubic (beta) around 1625° F. Alloying additions favor one or the other of these two structures, changing the transformation temperature or the width of the combined alpha-beta zone. Since different structures have different forming characteristics, alloy structure must be considered when dealing with titanium forming problems.

Titanium and its alloys are very reactive, combining readily with oxy-

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Circle 960 on Page 48-A

Ti in Aircraft . . .

gen, hydrogen and other gases. Excessive contamination may cause brittleness. Titanium can also react with tool materials to cause galling, welding and smearing in machining operations. Problems caused by reactivity can be avoided by controlling time, temperature and atmosphere when heating titanium, and by using the proper tools, coolant, speed and feed when machining.

Forming Titanium

Forming equipment must be powerful and rigid because of titanium's high yield strength. Sheet-to-sheet strength variations, plus titanium's low modulus, cause problems in controlling spring back. Forming at elevated temperatures reduces spring back and other problems related to high strength. However, you must always consider the effect of temperature on the two other factors, microstructure and reactivity. On all-alpha or alpha-beta alloys avoid heating to the all-beta region to prevent forming coarse, less-ductile structures. If the forming temperature is over 1100° F., remove the oxide skin by descaling and pickling. Low-temperature oxide, on the other hand, can be removed by pickling alone.

Several illustrations show how titanium parts are being made in the aircraft industry today. For example, inlet ramps for the North American AJ 3 are titanium-faced honeycomb. While titanium is used here primarily for its corrosion resistance, its high strength-to-weight ratio results in ramps weighing less than an all-aluminum version. The titanium face plates are machined to taper in thickness from 0.090 to 0.045 in. Warping is eliminated by submerging work and cutter in a pool of coolant, milling in a single pass, and changing cutters at the first sign of dullness.

An adhesive, HT-424, bonds the titanium plates to the honeycomb after the following four-step surface preparation: (*a*) vapor degrease, (*b*) acid pickle, (*c*) fluoride-phosphate coating, (*d*) hot water rinse.

An additional problem, drilling several thousand 0.05 and 0.06-in. diameter holes in the plates, is solved by using short-shank high-speed steel drills and a water-soluble oil coolant

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Circle 962 on Page 48-A

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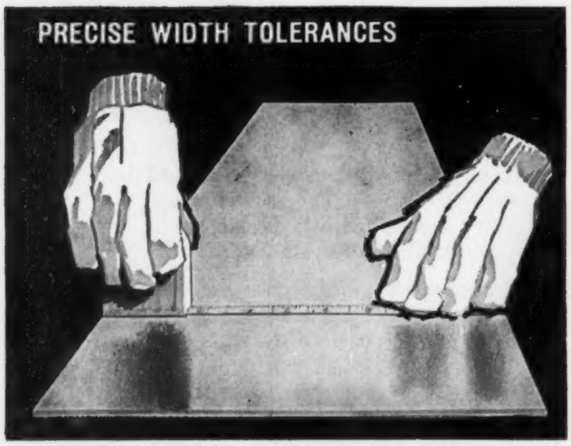

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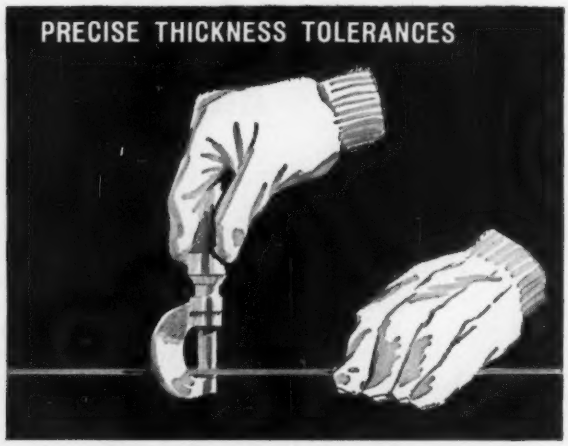

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Circle 963 on Page 48-A

Ti in Aircraft . . .

in a setup which bores 130 holes at a time.

Creep forming is used successfully by North American. Titanium parts, preformed on hydraulic presses or drop hammers, are brought to final size and shape by a combination of time, temperature and pressure in special hot bed presses. Parts are sized in 5 to 20 min., compared with 2 to 10 hr. by the previous methods.

The AJ 3 also uses titanium alloy extrusions and forgings. These are machined all over to meet proper dimensions, reduce weight, and remove contaminated surfaces.

An interesting method is used to reduce radiation heating around the J 70 engines in the AJ 3. Titanium structures surrounding the jet engine are sprayed with a gold-coating liquid used in the ceramics industry. The gold film reflects the heat, permitting lighter structure than would be needed otherwise.

Reliability is steadily improving in titanium mill products. An example of this is hydrogen contamination. In a 1954 survey, less than half of the titanium sheet samples tested had under 150 ppm. hydrogen. Slightly more than a year later, the industry improved the product to the point where 85% of the sheet tested met the hydrogen specification. Data also show that yield strength uniformity of commercially pure titanium improved between 1955 and 1957.

Titanium fabrication is becoming very reliable. The AJ 3 uses about 100 parts machined and formed from 5 Al, 2.5 Sn titanium extrusions. Scrap losses today are only 2%, compared with 85% a year ago when this particular program was first started.

Service reliability of titanium is excellent. Aircraft metallurgists report that after titanium parts pass final inspection, they seldom cause any problems. Pratt and Whitney report more than 1,000,000 flight hours on 5800 engines containing titanium without a singe instance of failure recorded. B. L. SHAKELY

Use of Radio-Isotopes in Production

Digest of "The Industrial Radio-Isotope — Oversold or Underbought?", an address by P. C. Aebersold of the Atomic Energy Commission's staff before the National Assoc. of Manufacturers, New York, May 26, 1959.

WITH PARDONABLE ENTHUSIASM, Mr. Aebersold proclaims that "thar's cold cash in hot atoms!" Consequently he thinks that radioisotopes are underbought rather than oversold, a matter which may take some time to correct, because industry must learn about their potentialities in *production*, not merely in research. There is a vast realm of unextended and "unborn" uses.

For example, look at penetration of matter by gamma rays, known for over 50 years. In that period radium was used; "it is, however, expensive, has a wide range of gamma rays from low to very high energy, and gives off hazardous radioactive products such as radon. These properties restrict its applications. With the nuclear reactor we can make gamma

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Circle 985 on Page 48-A

Radio-Isotopes . . .

ray sources that are far more intense and compact, less expensive, quite homogeneous in energy, and much safer. By combining the newer gamma ray sources – such as cobalt 60, cesium 137 and iridium 192 – with improved electronic radiation detectors, countless uses for gaging and controlling the thickness and density of all kinds of industrial material produced in sheet form or thin sections, and for monitoring contents of containers, and gaging of liquid levels have been developed."

Radiography of welds is a common method of nondestructive testing. A single ship's hull may require 10,000 negatives. Every joint in an overland pipe line is radiographed. It is no longer necessary to use the fishpole technique with the accompanying possibility of easily losing the small capsules of radio-cobalt. Shielded containers from which the source is cranked out through a narrow tube like a garden hose are now available for all scales of operation. The isotopic radiography unit is also much simpler to operate than an X-ray machine. Labor costs in using it are much lower, and downtime and malfunctions are almost unheard of.

Over 4000 radio-isotopic gages are now used throughout American industry. Their principle is old and simple – gamma or beta rays of a particular energy are absorbed by matter in a manner dependent on the mass (thickness) and atomic composition. Other devices using the reflection principles can measure the thickness of walls of pipes and tanks suspected of corrosion. Another device is a corrosion mapper to measure corrosion or erosion in heat exchangers, by gamma ray back scatter. Radiation sources, such as krypton 85 used in these gages, are becoming better and safer. Krypton is a noble gas, does not enter into the metabolic systems of the body, and therefore is safe to use. If the source container is broken the gas will simply dissipate harmlessly into the atmosphere.

One important recent extension of utilities is "double gaging", which simultaneously controls the thicknesses and densities of two different materials in contact. These materials may be two metal sheets, or a ceramic coating applied to a metal strip. The gages use two different isotopic sources of radiation, and the device will separate photopeak lines by a scintilation detection system of high resolution.

Isotopic tracers are familiar to all research men. "Important as tracers have been and will continue to be in analysis, process improvement and trouble shooting, the really great industrial potential lies in the actual incorporation of tracer isotopes in materials in process. In that manner, it would be possible to have immediately available at all times an extremely accurate inventory of every part of the plant, as well as correct, continuous data on plant operations."

Automatic Factory – "This leads to the possibility of the *completely automatic* processing plant. Since the information provided by isotopes is in the form of electrical impulses, these can be fed to electronic computers and the data supplied to

Circle 966 on Page 48-A

Circle 967 on Page 49-A

Radio-Isotopes . . .

management in the form best suited for decision making. In such an automated plant, all inflowing raw material would be weighed and the flow of materials throughout the plant would be monitored by nuclear gages. Each process operation would be controlled by electronic equipment using radiation detection instruments as 'radioeyes'. At the same time, and from any number of points within the factory, process data on speeds, rates, power consumption, and machine conditions would continuously be fed to a central data reduction center. This would contribute enormously to efficiency and productivity."

Safety – "That radio-isotopes can be used with great safety should be emphasized. A typical radiation source in a nuclear thickness gage will demonstrate this. First, the radio-isotope is deposited in a chemical form that is very insoluble. This chemical is then mixed with gold powder, compressed, and covered with solid gold. Thus it is not only impervious to almost any chemical reagent, but in the unlikely event of a fire hot enough to melt gold, all the radioactivity will dissolve in the gold and run along with it rather than be scattered about. In addition to these obvious safety features, the source is mounted inside the gage in such a way that any tampering with it sets off alarms.

"It should be emphasized that radio-isotopes are safe because their radiation can be detected in almost infinitesimal amounts – levels of a thousandth or even a millionth of the level at which they are believed to be perfectly safe. This is a tremendous margin of safety."

E.E.T.

Welding Titanium

Digest of "Inert-Gas Tungsten-Arc Welding of Titanium for Nuclear and Chemical Industries", by G. M. Adamson and W. J. Leonard, *Welding Journal*, July 1958, Vol. 37, p. 673-682.

FIELD AND BENCH welding procedures for high-purity "unalloyed" titanium are described. These employ inert-gas tungsten-arc welding

(Continued on page 210)

Shown is a Drever Gas-Fired Strip Belt Conveyor Furnace for reducing and drying copper powder at the rate of 10 tons per 24 hours at 1000°F.

In the foreground is a Drever Inert Gas Generator for supplying the necessary gases to purge the furnace entry and exit areas.

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for metal powders

In the manufacture of metal powders, an essential step is the ability of a furnace to completely reduce and dry metal powders and obtain powder of uniform particle density. Experience proves Drever Strip Belt Conveyor Furnaces meet these rigid specifications.

Completely integrated sheet belt furnaces are available for treating oxides of nickel, iron, copper and tungsten. Powder is received from a hopper, leveled on belt and conveyed through a highly reducing atmosphere in the heating and cooling chambers.

Specially designed roll seals keep furnace openings tight while the areas are purged with inert gas. Complete temperature control as well as product uniformity is inherent in the design of these furnaces. They are available for fuel firing, radiant tube or electric heating.

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35

Circle 969 on Page 48-A

This Lindberg Furnace, Model CT3848-A, is being used at Ingersoll Milling Machine Company, Rockford, Illinois, for hardening Ingersoll inserted blade milling cutter bodies and also for gas carburizing. It is equipped with Lindberg's exclusive CORRTHERM electric heating elements. Temperature range 1850° to 2000°F.

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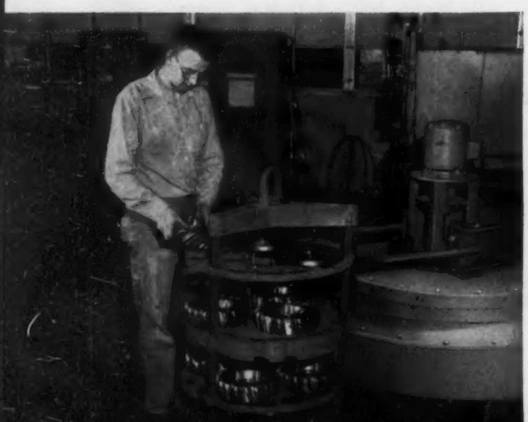

Fixture being loaded with work while furnace is treating another load. Treated load will be removed and new load inserted quickly and easily.

CORRTHERM heating elements operate at extremely low voltage so heat leakage through carbon saturation is eliminated and shock or short hazard prevented. Makes possible use of electricity for carburizing without furnace retort.

Welding Titanium . . .

equipment. Neither α-β titanium alloys, which are essentially unweldable, nor α alloys are discussed.

Two miniature types of dry box, attached to the welding torch, were developed. The successful type comprised a metallic trailing shield, shaped to weldment contours and especially suitable for machine welds. In a less satisfactory type, a ceramic trailer, forming an integral part of the torch hood, gave single pass butt welds with hardnesses over Vickers 200 indicating contamination. The roots of welds are protected with inert gas by special purging attachments. A third type of portable dry box involved an inflatable plastic bag, completely enclosing weldment and tools, fitted with gloves, and held to the work with slip rings.

The quality of the welds was assessed by conventional methods, metallographic examination, and bend tests. Hardness surveys gave oxygen contents. Quality standards were established in conventional dry boxes using a welding technique modified from that for Type 347 stainless steel. The investigation covered all the welding variables for tungsten-arc air welding, and complete specifications were laid down for welding thicknesses from 0.020 to 0.750 in. with a metal trailer torch. Welding temperatures are kept low by employing reduced power input and controlled interpass temperatures. The stringer bead technique is preferred to weaving, which gives shielding difficulties. Hardness values in the range Vickers 123 to 205 (10-kg. load) for the metal trailer torch welds indicate oxygen contents and mechanical properties, which were also measured, comparable to conventional dry box welds. Acceptable pipe welds were made to A.S.M.E. Boiler Code.

The color of acceptable welds ranges from gold to dark blue; dark oxide colors formed on cooling are harmless in single-pass welds, but must be removed from multipass welds. Welds with rainbow or dull translucent silver colors are rarely sound. Hardnesses up to Vickers 240 (10-kg. load) give satisfactory welds.

Gas flow should not fall below 8

Welding Titanium . . .

cfh. Inert gas protection of the root is essential before welding starts. As a shielding gas, argon is preferable to helium due to its high density, but helium imparts more stable arc voltage characteristics. In field welding where contamination is the main problem, argon is preferable, but when shielding is not so critical, helium-argon mixtures are advantageous. Gas of 99.99% purity is essential.

The filler wire must always have a higher purity than the base metal for equivalent weld properties.

The corrosion resistance of titanium and stainless steel to acid uranyl sulphate solutions at up to 300° C. (575° F.) was satisfactory under mild conditions, but titanium was superior for concentrated solutions and high liquid velocities. Welds operated without failure in corrosion loops circulating uranyl sulphate solution at 250 to 300° C. (480 to 575° F.) and 1000 to 2000 psi. for three years, and a loop has been used in a reactor satisfactorily.

These welding procedures are especially applicable to field welding of nuclear and chemical plants; price and quality compare with stainless steel.

P. D. Blake

Coatings of Chromium

Digest of "Electrodeposition of Black Chromium Coatings", a bulletin published by Solvay Process Div., Allied Chemical Corp., New York.

A RECENTLY revealed method for electrodepositing black chromium plate uses reasonably low current densities of 75 to 450 amp. per sq.ft. Other known processes require current densities of more than 600 amp. per sq.ft. The black coatings are said to have the chemical resistance and wearing qualities of chromium while also being wettable with oils. Usually, chromium plate needs a special treatment to make it "porous" for oiliness in antifriction uses.

The new plate needs no postplating treatment, being black as deposited from a chromic acid bath containing only fluoride and no other catalyst. Sulphate, a usual catalyst in chromium plating, is especially

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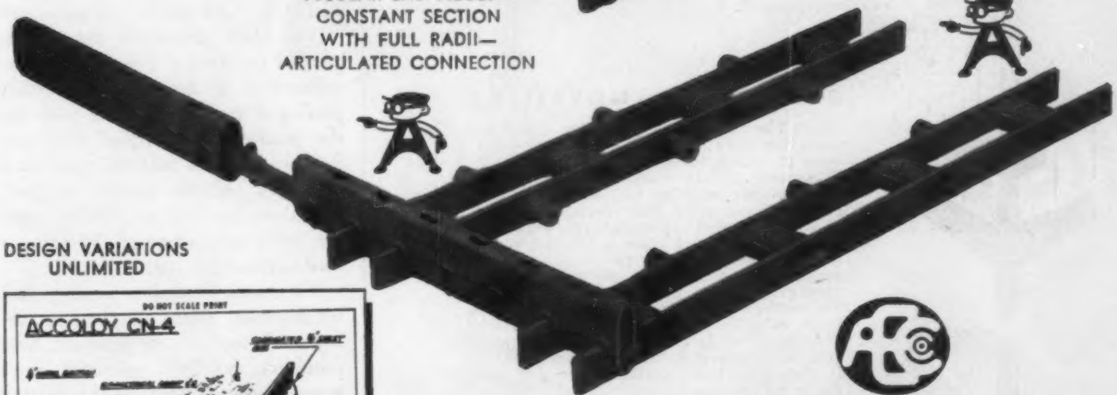

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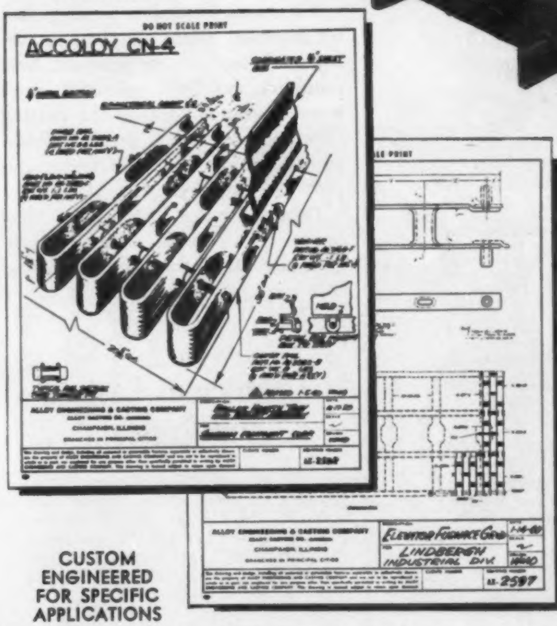

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Circle 974 on Page 48-A

Cr Coatings . . .

undesirable and must be removed. Nickel is required as the basis surface, and can be provided by nickel plating any material on which the black chromium is desired.

The black chromium plating bath contains 200 to 300 g. per l. CrO_3 and 0.125 to 0.50 g. per l. (H_2SiF_6) or 0.125 to 1.0 g. per l. ammonium fluoride (NH_4F) for plating at 300 amp. per sq.ft. for 5 to 40 min. at 90° F. Sulphate is removed from the plating bath by treatment with barium chromate or barium carbonate. The temperature range of 80 to 95° F. and the current density range of 125 to 450 amp. per sq.ft. is ample for practical applications. Plating bath control by hydrometer and Hull cell is simple and practical.

The black chromium can be deposited on itself. This permits examinations if desired, and further plating if necessary. The tank for the plating bath is lined with any fluoride resistant material such as a polyvinyl chloride plastic or lead. Tantalum heating or cooling coils are preferred, although lead-tin or lead-antimony is usable.

The black chromium is suggested for firearms, electronic parts requiring black surfaces for emission, heat radiation, no light reflection, and wear resistance because the coating wets with oil, wax, organic fluids, which also improve the luster and protective quality.

Costs are not mentioned, but they appear comparable with those of conventional chromium plating at 300 amp. per sq.ft.

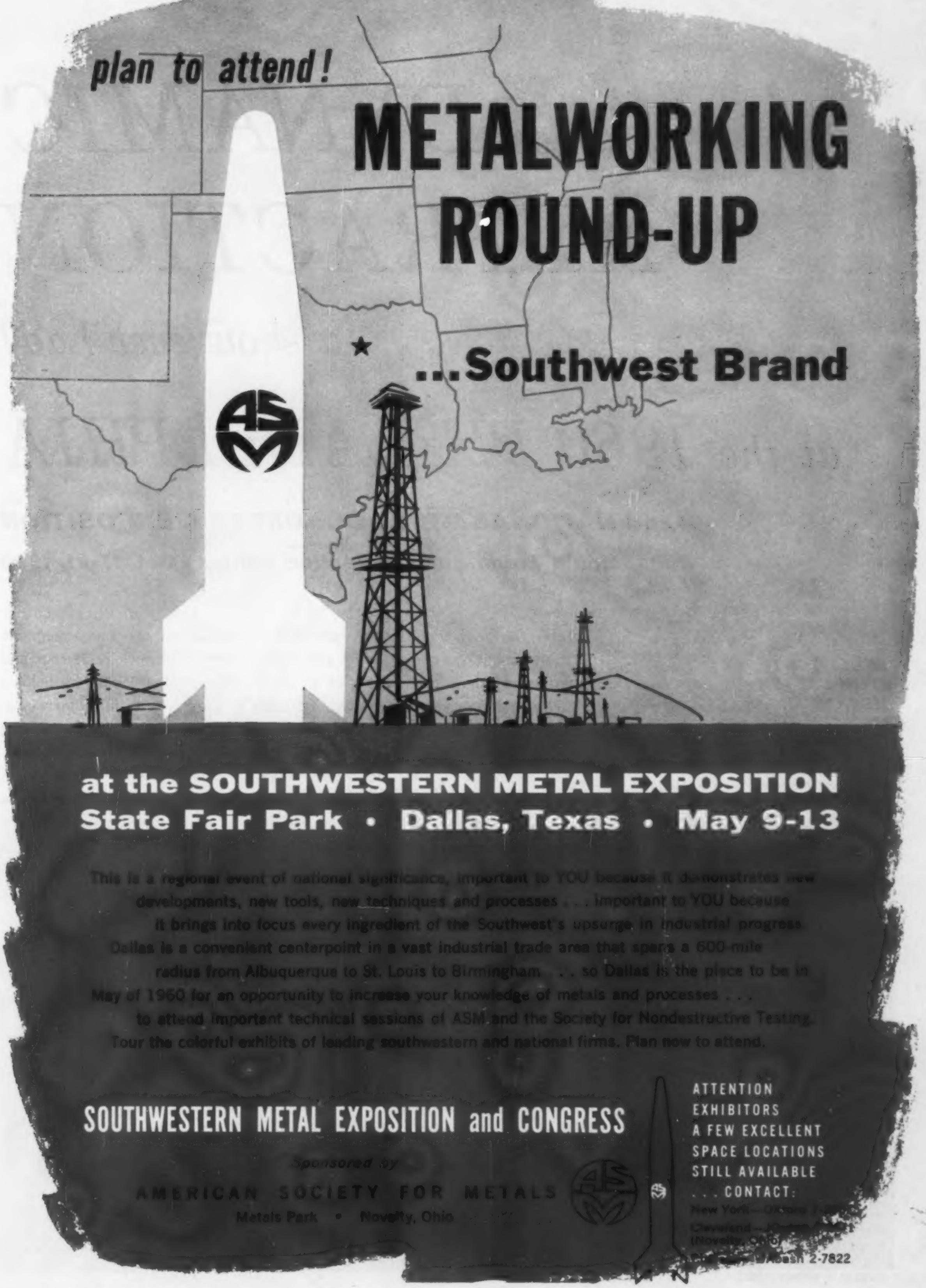
C. L. Faust

Continuous Casting in Russia

Digest of "Continuous Casting of Steel in the USSR", by M. S. Boichenko, V. S. Rutes, D. P. Evteev and B. N. Katomin, *Journal of the Iron and Steel Institute*, Vol. 191, February 1959, p. 109-121.

An interesting article on continuous casting describes five Russian installations. Three are pilot plants; the others are regular commercial installations. The first commercial installation was started up at the Krasny Oktyabr works in Stalingrad

(Continued on page 118)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METAL SHOW

Casting in Russia . . .

where slabs 6 × 24 in. and 7 × 12 in. were cast of stabilized 18-8 stainless steel. The installation consists of two machines, and it can produce billets up to 22 ft. long. A new plant is being installed to cast slabs up to 32 ft. long. An additional machine was installed at Kirov works in Leningrad in 1953 to produce killed carbon steel in 8 × 8-in. to 14 × 14-in. blooms. Two commercial plants are located at the Nova Tula works and the Krasnoye Sormovo plants.

Russian practice in continuous casting is in two ways quite a bit different from that in the United States and other countries. The two commercial plants operate with the casting machine extending into a pit about 20 ft. deep, and the pouring station is about 12 ft. above floor level. This eliminates the very high towers which exist in the United States, and no elevator is needed to lift the pouring ladle. Another departure at the Russian plants is a set of eight pinch rolls (four on a side) which guide the ingot through water sprays when it leaves the water cooled mold. The Russians claim that only about one-third as much water is needed for cooling by use of these four pinch rolls. Another innovation in the Russian practice is to pour the steel into a tundish with outlets for two casting molds. The tundish is also covered and closed except for the opening to receive the steel.

Pouring rate is about 10 tons per hr. per mold; by using two molds, a 10-ton ladle can be emptied in 30 min. The molds are made of copper with a face thickness of 15/32 in. Such molds exhibit the least amount of transverse waviness, and can be repaired several times by machining the copper working faces of the mold. This thickness is much greater than that encountered in the experimental plants in the United States.

The Russians have done a lot of work on the secondary spray cooling of the ingot as it leaves the mold. When too drastic cooling was employed (using 0.27 gal. per lb. of

PART: Welded bellows-type seal. **MATERIAL:** Type 410 Stainless Steel. **SPECIFICATIONS:** To be hardened under close control because of variations in metal sections. Finished assembly to be clean, bright and free from oxides and scale. Seal in photo has been cut to show cross section of the bellows-type seal.

How would you heat treat a part like this?

The stainless steel bellows-type seal shown is used in a number of applications, from refrigerating systems to missiles, where mechanical seals are needed to resist extreme temperatures from —400F to +1200F. Heat treatment is complicated by the wide variation in section between the thin bellows and the much heavier outer rings.

The Sealol Corporation, Warwick, R. I., solves the problem with a Hayes electric furnace equipped with GLOBAR® silicon carbide heating elements. Depending on the material of the welded bellows (stainless steels of the 300 and 400 groups, precipitation hardened steels such as AM350, 17-7PH, Inconel X, etc.), hardening is between 1700F and 1900F, followed by muffle cooling, both in a hydrogen atmosphere.

GLOBAR elements make possible the precise temperature control and clean heat, independent of the atmosphere, required in this critical operation. Rod-type element simplifies design, furnace construction and servicing. Losses are minimized because all heat is produced and contained inside the furnace.

The many advantages of heating with GLOBAR elements often more than cancel out differentials in BTU costs between electricity and other fuels. Why not investigate with your furnace builder—or write to Refractories Division, Globar Plant, Dept. MP-30, The Carborundum Co., Niagara Falls, N. Y.

For precise, economical electric heating

GLOBAR
silicon carbide
heating elements

- Shipped from stock or within two weeks.
- Temperatures from 1400 to 2800 F, precisely controlled, independent of atmosphere.
- Easily replaced from outside without waiting for furnace to cool.
- "On line" operation for many applications—no transformer necessary.
- Rods 4" to 105" in length.
- For greater economy in heat treating, brazing, forging, melting, and sintering.

For latest advances in silicon carbide heating elements . . . count on

CARBORUNDUM®

Circle 977 on Page 48-A

Casting in Russia . . .

steel with the cooling zone only about 3 ft. long), cracks developed in the ingots due to the severity of the quench. This was particularly evident in the high-carbon steels. They state that the basic requirement of a secondary cooling system is uniformity of cooling throughout the zone of freezing. Support rollers must be installed for the entire length of the cooling zone. One large installation has over 13 support rollers in the cooling zone. This number gives a good example of the extreme lengths to which the Russians have gone in the secondary cooling.

Very good drawings of the mold, the tundish and the cooling rollers are shown in the paper, and etch tests are shown of numerous carbon and stainless steel castings produced in these machines. A 4½% silicon transformer steel is shown with very coarse grains in a square section, with extremely coarse dendrites leading from the mold wall to the center of the ingot. This is typical of this type of steel. The etch test on the slab molds of low-carbon steel also show this ingotism, but a much finer grain structure. Both low-carbon killed steels and rimming steels are cast in these machines and they seem to be producing a superior product.

E. C. Wright

Welding Copper Alloys

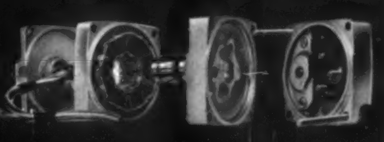
Digest of "Welding of Cupro-Nickel and Aluminum Bronze Alloys", by C. A. Terry and E. A. Taylor, *British Welding Journal*, Vol. 5, May 1958, p. 211-225.

Cupro-nickel alloys and aluminum bronzes find extensive use today under corrosive conditions. The weldability of these alloys is assessed.

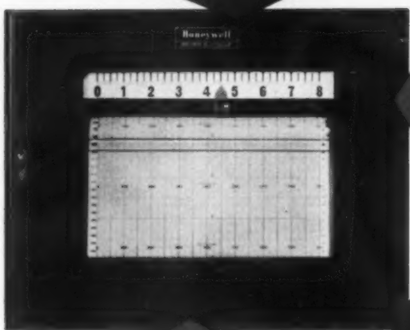
The wrought binary alloys (cupro-nickel type) are almost entirely single-phase solid solutions. Any slight susceptibility to crack during welding or rolling is eliminated by holding sulphur, lead and phosphorus to low limits. In all autogenous welding processes, gas porosity can arise from hydrogen and oxygen ab-

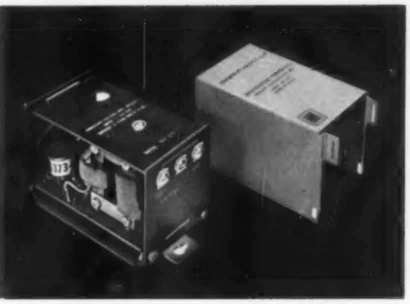
(Continued on page 226)

MODULAR DESIGN MAKES 1960 *Electronik* POTENTIOMETERS A GREATER VALUE THAN EVER



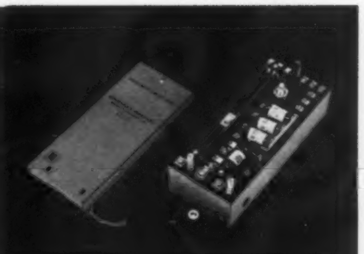
BALANCING AND CHART DRIVE MOTORS are sectionalized. Service is simplified because any major part can be replaced in a matter of seconds.





CONSTANT VOLTAGE UNIT* eliminates need for batteries, standard cells, and standardizing mechanisms . . . insuring long life.

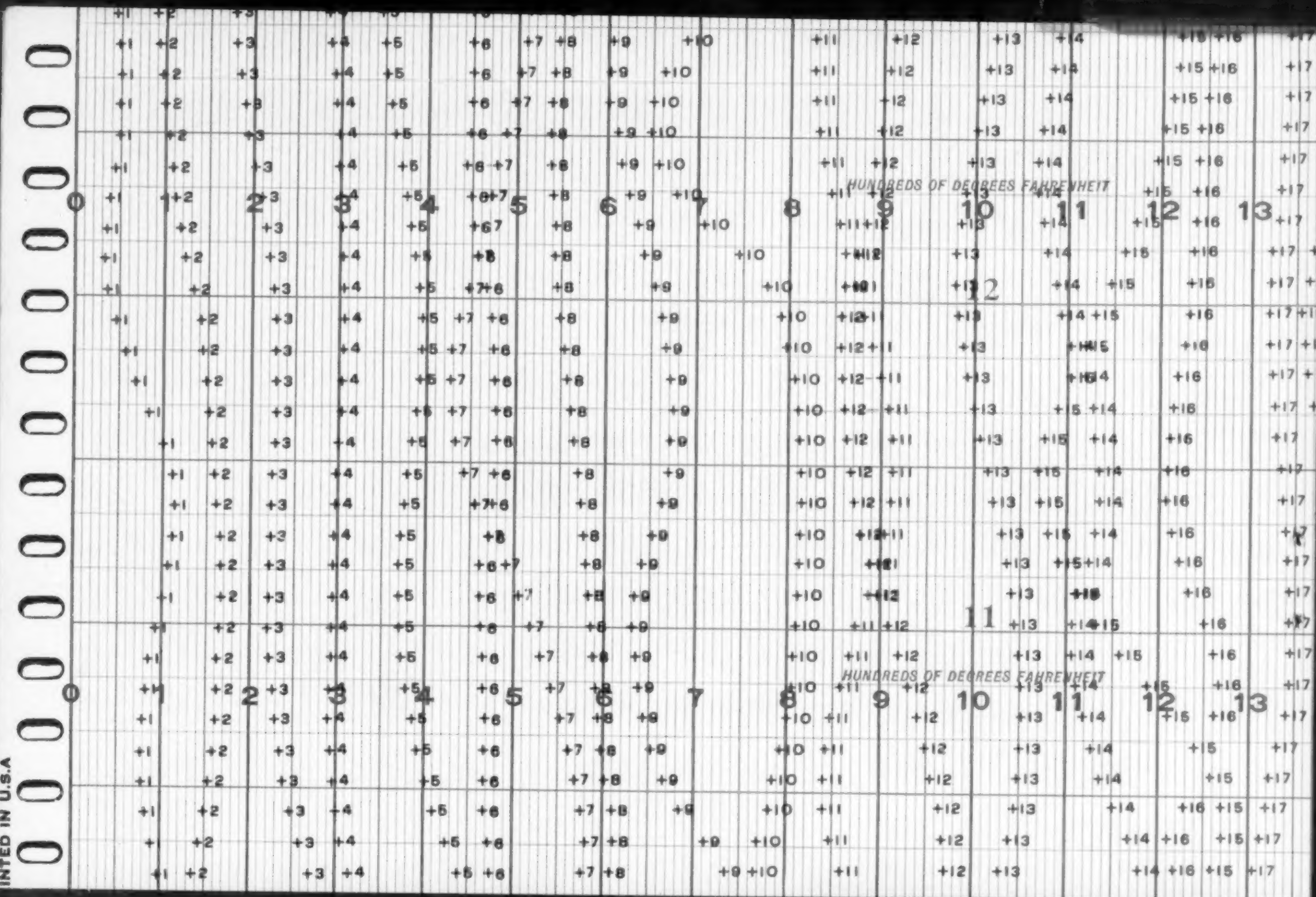
*Zener Diode



COMPARTMENTED MEASURING CIRCUIT UNIT makes range changing easy. Change one screw on a clip connected card of fixed resistors, and the job is done in a matter of seconds.

QUICK-CONNECT AMPLIFIER is easily removed from the instrument by means of a polarized plug.

BUT THIS IS JUST PART OF THE STORY OF THE 1960 LINE OF ELECTRONIK POTENTIOMETERS. LOOK AT THE DRASTIC CHANGES IN THE ELECTRONIK MULTI-RECORD RECORDERS.


HUNDREDS OF DEGREES FAHRENHEIT
INTED IN U.S.A

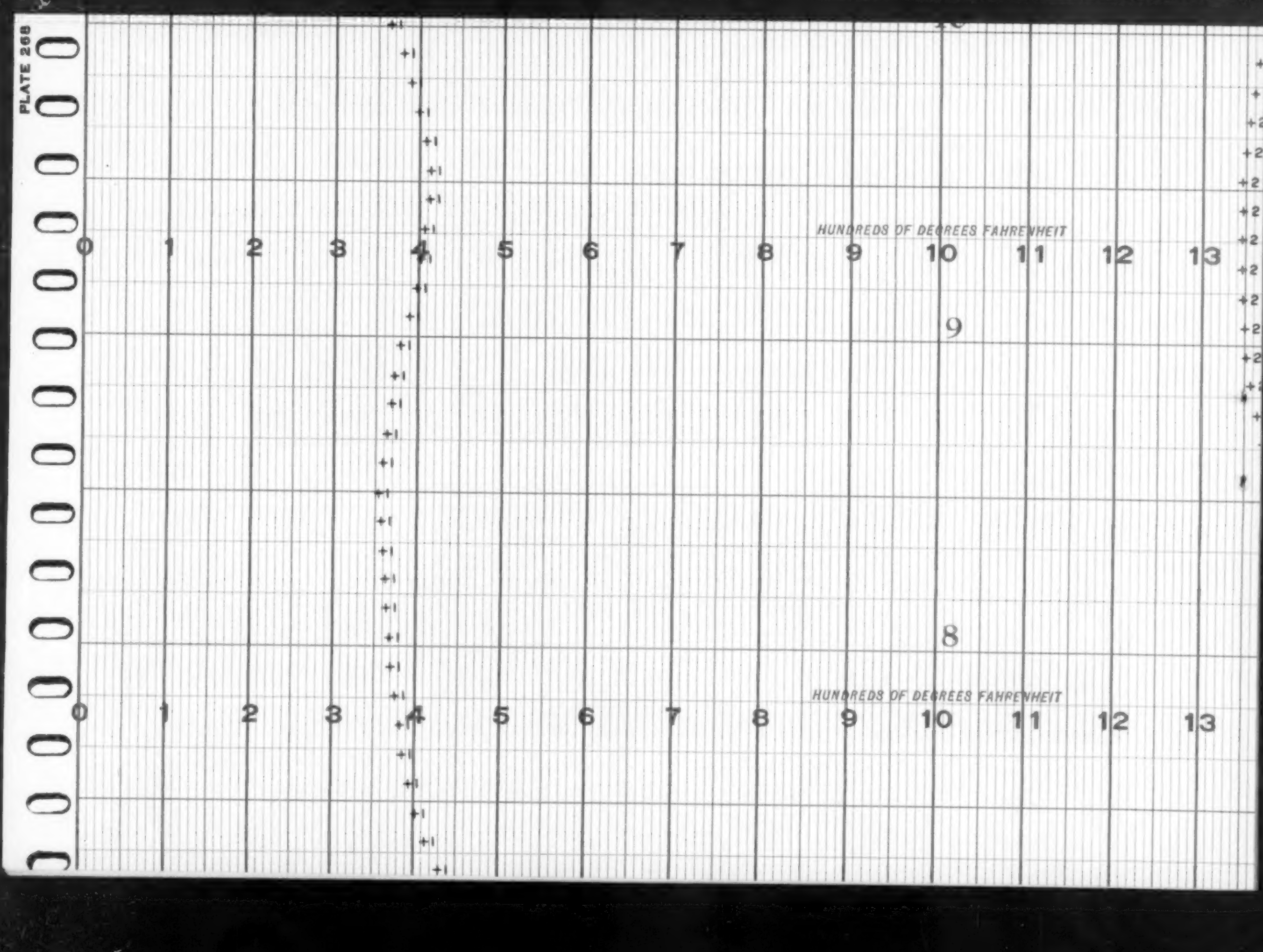
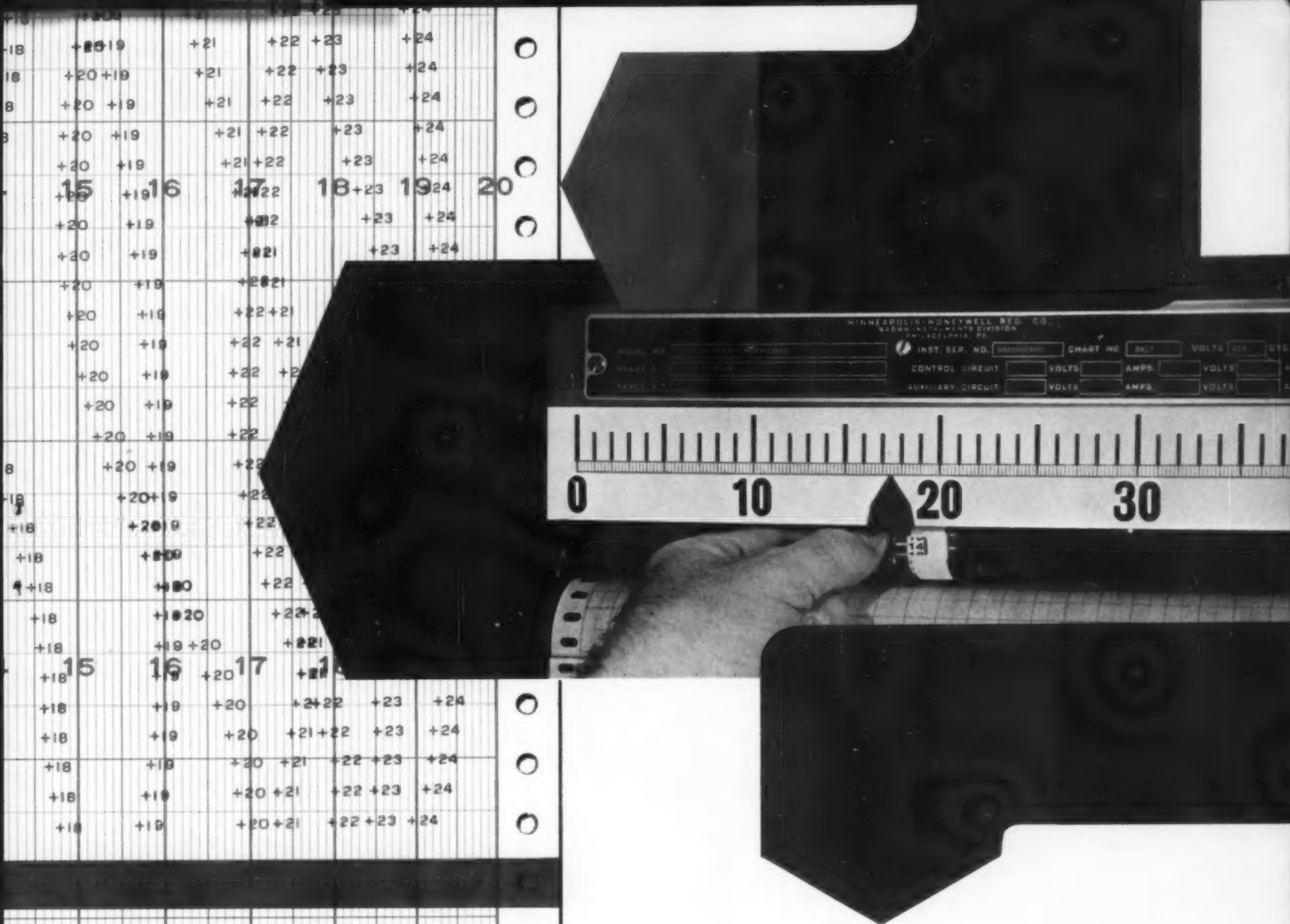
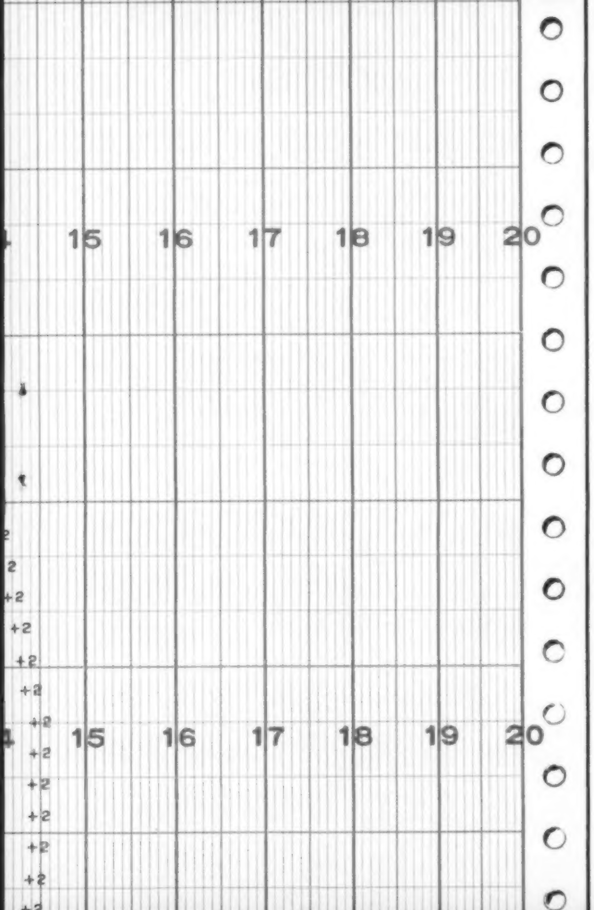


PLATE 268
HUNDREDS OF DEGREES FAHRENHEIT





Record 2 to 24 points on one instrument with new UNIVERSAL *ElectroniK*

MULTI-RECORD INSTRUMENT

Now, you can record 2,3,4,6,8,10,12,16,20, or 24 points on one ElectroniK Multi-Record Instrument... and change the number of points to be recorded in a matter of seconds. It's easy as this: remove a thumb-tight nut and slip off old print wheel . . . and indicator dial. Slip on a new wheel and dial: Replace nut. Plug in the number of points desired, and the job is done.

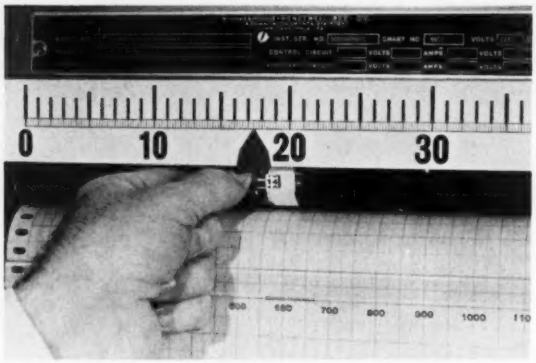
The universal features and modular design of the 1960 line of ElectroniK potentiometers are standard on all multi-record non-control models. Range and compensation changes are quick and easy, too . . . just change the cards.

FROM HONEYWELL... A DIAMOND JUBILEE PARADE OF PRODUCTS

SEE HOW EASY THE 1960 ELECTRONIK MULTI-POINT RECORDERS ARE TO USE...

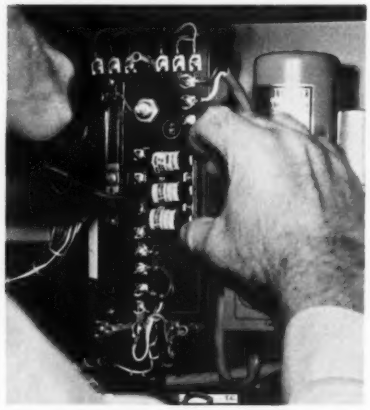
all it takes with the 1960 *ElectroniK* MULTI-RECORD RECORDERS to change . . .

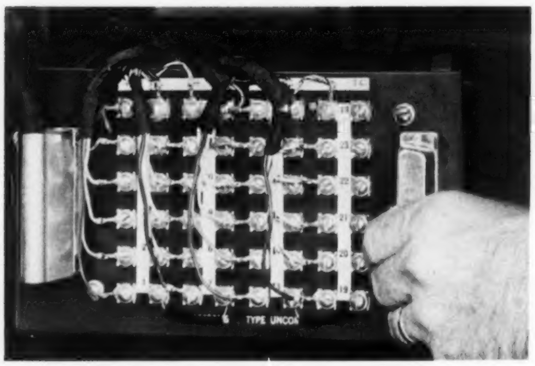
. . . number of points recorded



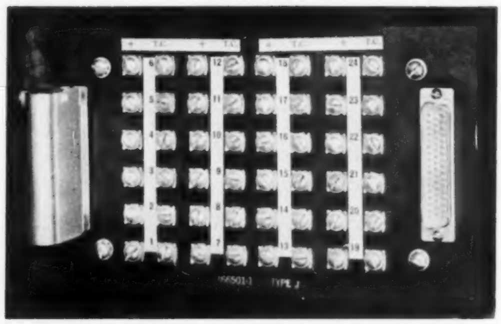
First: remove thumb-tight nut; slip off print wheel and indicator dial. Slip on new wheel and dial and replace nut.

. . . RANGE—Loosen screws and slide out the range resistor card. Replace with a different card, tighten screws and the job is done quickly and easily.





Second: replace one plug-in unit and the instrument is ready to record a different number of points.



. . . COMPENSATION—The input terminal board with built-in reference junction comes out by removing one plug. Slide in the new board, replace the screws and plug and the compensation is changed.

The new flexibility and convenience of the 1960 ElectroniK Multi-Record Recorders should interest you. This new design has resulted in substantial manufacturing cost reductions which are reflected in our new price structure. Your nearby Honeywell field engineer has the full details. He's as near as your telephone. Minneapolis-Honeywell, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

First in Control

SINCE 1885

75th YEAR PIONEERING THE FUTURE

Circle 979 on Page 48-A

Welding Cu Alloys . . .

sorption by the weld pool. Fine general porosity is less dangerous than large localized blowholes.

Sound welds of high strength are obtained with the argon arc process (a-c. or d-c.) by using special deoxidizing filler alloys, to the extent of 50 to 60% of the weld in butt joints. This process can deal with up to about ½-in. plate.

Deoxidizing filler alloys must also be used with the inert-gas, metal-arc process to insure freedom from porosity. This process is capable of high welding speeds. Sound vertical and overhead welds are possible if the filler wire diameter is reduced from the normal 0.062 to 0.045 in. It should be used for material over 3/16 in. thick.

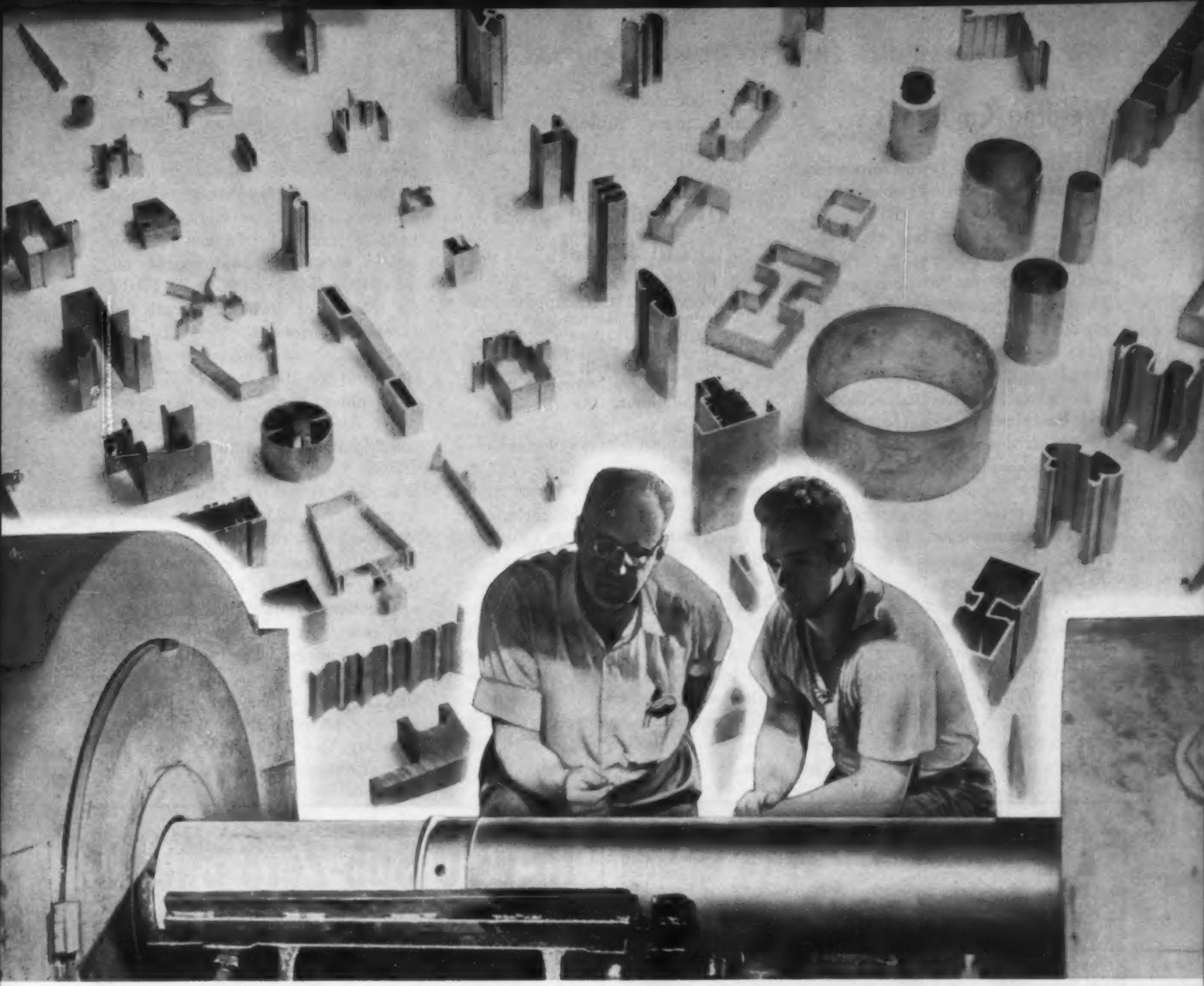
Until recently, metal-arc welding has been performed by coated electrodes with special Monel core wires, but better results are being obtained with 70-30 cupro-nickel electrodes such as Inco 137. New Murex electrodes of improved performance are under development, using inert-gas metal-arc type filler wires as core wires.

Gas welding of cupro-nickel alloys requires skill, and is limited to sheet under 1/16 in. thick. Boron-free proprietary fluxes must be used, and improved weld quality is obtained by using deoxidizing 80-20 cupro-nickel filler rods.

Aluminum bronze alloys contain aluminum in the range 4 to 11%, with iron, nickel and manganese additions. Design stresses and constitutional diagrams are given for the A.S.T.M. alloys A, C, D and E, the D.T.D. alloys 197 and 164 A and Superston (13% Mn). Alpha-phase alloys have below 7% aluminum, and increasing amounts of β-phase are present in the heat-affected zone of the weld at high aluminum contents. On cooling to 565° C. (1050° F.), the β phase transforms partially to the hard brittle σ phase, leading to lowered ductility. Sound butt welds can be made in α and $(\alpha + \beta)$ alloys, despite some susceptibility to hot cracking. Hot cracking, observed in 93 Cu, 7 Al α alloys, may be attributed to trace impurities (probably lead and bismuth) precipitated at grain boundaries, embrittlement being most pronounced at 650° C. (1200° F.). The complex $(\alpha + \beta)$ alloys are relatively less affected.

In welding aluminum bronzes, the aluminum oxide film must be dispersed. This occurs automatically with the work negative as in the inert-gas metal-arc process, alternating current achieving dispersal in the tungsten arc process. Welding procedures and weld properties are given for these two processes and for metal-arc welding.

Sound butt welds were obtained by both the tungsten argon-arc and inert-gas metal-arc processes using the filler wires 93 Cu, 7 Al, alloys D and E and Superston, but not using the special 93 Cu, 7 Al alloys containing extra aluminum, nickel and iron. A sealing run is recommended with butt welds. Of various hot cracking tests tried, the Houldcroft "fish bone test" gave the most consistent classification, which, in order of decreasing resistance, was 93 Cu,



Welding Cu Alloys . . .

7 Al, alloy E, alloy D and Superston. Root embrittlement was encountered in seven-pass welds by the inert-gas metal-arc process, in line with other investigations, but not in five-pass welds by the tungsten-arc process. This embrittlement was not associated with grain boundary films of σ_2, as has previously been suggested, films being present on ductile welds.

In metal-arc welding, Shedden and Pumphrey's work (*Journal*, Institute of Metals, Vol. 83, 1954-55, p. 562) shows that 87-10-3 Cu-Al-Fe core wires deposit duplex ($\alpha + \beta$) alloys of great strength, which are crack resistant even in multipass welds. Difficulties arise in welding α alloys, however.

Gas welding is not really recommended for aluminum bronzes. For thick sections, carbon-arc welding, using covered filler rods has advantages. Weld cracking in the aluminum bronzes is largely due to incorrect technique. Both embrittlement and hot cracking may be caused by grain boundary segregates of impurities more soluble in the β than the α-phase.

P. D. Blake

Titanium and Steel in Aircraft

Digest of "Future Application Trends for Titanium and Steel in Military Aircraft", DMIC Memorandum 17, May 8, 1959, Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio.

This report presents condensed data obtained from over 80 aircraft companies and government agencies. The one table included is labeled as "a sweeping simplification of the detailed statistics on which it is based". The report also states that it "seems entirely proper . . . to use average percentage figures to show trends in material usage in airframes". These quotes from the text are included since the qualifications built into the report are important considerations which any reader must bear in mind.

The period covered by the report is summarized in figures for three years, 1961, 1965 and 1968. Use percentages are stated on a per plane or engine basis. No estimate of the number of planes or engines to be built is included. In general, the article foresees a considerable increase (double in 1965 over 1961) for the use of titanium in both engines and airframes. Very little increase in either titanium or steel is projected for 1968 over 1965.

To obtain their figures, the compilers decided that the application should have a minimum temperature of 300° F. and that steel should have a tensile strength over 200,000 psi. in pressure vessel-type applications. With regard to titanium in this latter type of application, the report states that the usefulness of titanium in these applications is established, but actual use awaits testing which will probably be underway for the next year or two. The impression is gained that missile applications, although already established for steel, are affecting the statistics on titanium

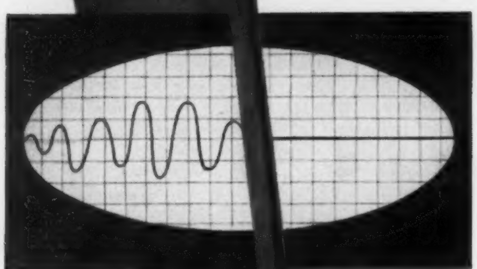
(*Continued on page 232*)

Circle 985 on Page 48-A

New Fabric Uses POWDERED LEAD

To Hush Jetliner's Roar

Ounce-conscious aircraft designers find LEAD worth its weight in unique sound attenuation properties



Sound attenuation is the ability or property of absorbing or deadening sound—and lead was the only material that could do the job effectively and inexpensively in this new airborne acoustical fabric.

Called Coustifab*, the new material is made of either cotton or glass fabric coated with Goodrich Geon polyvinyl material compounded with *powdered lead.* It is being used in the ceilings and rear side panels of the new Douglas aircraft to absorb low frequency vibrations which normal acoustical material cannot handle.

This exceptionally flexible way of using lead opens new avenues of application for this versatile metal. By varying the lead content which may run as high as 80% by weight depending upon the specific use, the new fabric may have a wide potential for office machines, X-ray rooms, building materials, industrial plants and other places where the unique silencing or protective properties of lead are required.

Product of Cordo Chemical Corporation, Norwalk, Conn.

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The Largest Producer Of Lead In The United States

PB-148

Circle 998 on Page 48-A

Circle 991 on Page 48-A

Titanium and Steel . . .

hardly at all. This implication is further born out by the statement made in the report that the missile applications are lumped with airframes. So much for the actual numbers in the report.

The report does not give any technical details involved in the choice of one material over the other. One point is made clear, the high price of titanium continues to limit its use. Other deterrents are restricted availability and lack of data. It might have been better to say that comparative costs and unfamiliarity with the material on the part of both designers and manufacturing units are deterrents to further titanium usage. The "restricted availability" statement is qualified because it applies to alloys which have the same strength as steel in the 200,000 psi. yield strength range. With the titanium industry operating at less than 25% of capacity, availability of either experimental materials or established ones is no problem. Existing titanium-base alloys, which have been through production development in producers' plants and which will meet 200,000 psi. tensile, without density considerations, are available. Design data are scarce for both the very high strength steels and the high strength titanium alloys. It is apparent from the report that both aircraft companies and government agencies are reluctant to set a price which can be paid for weight saving.

Your reviewer is inclined to think that current and perhaps justified dollar consciousness on the part of the military, and emphasis on the weapon system concept which tends to ignore detailed material and component development, are the major factors affecting the wide uses of unusual materials like titanium.

Problems in welding and brazing titanium are indicated as deterrents to its use. These are very important considerations, particularly in the development of applications in the missile field. Extensive and expensive development programs are still required to expand the use of titanium in all fields.

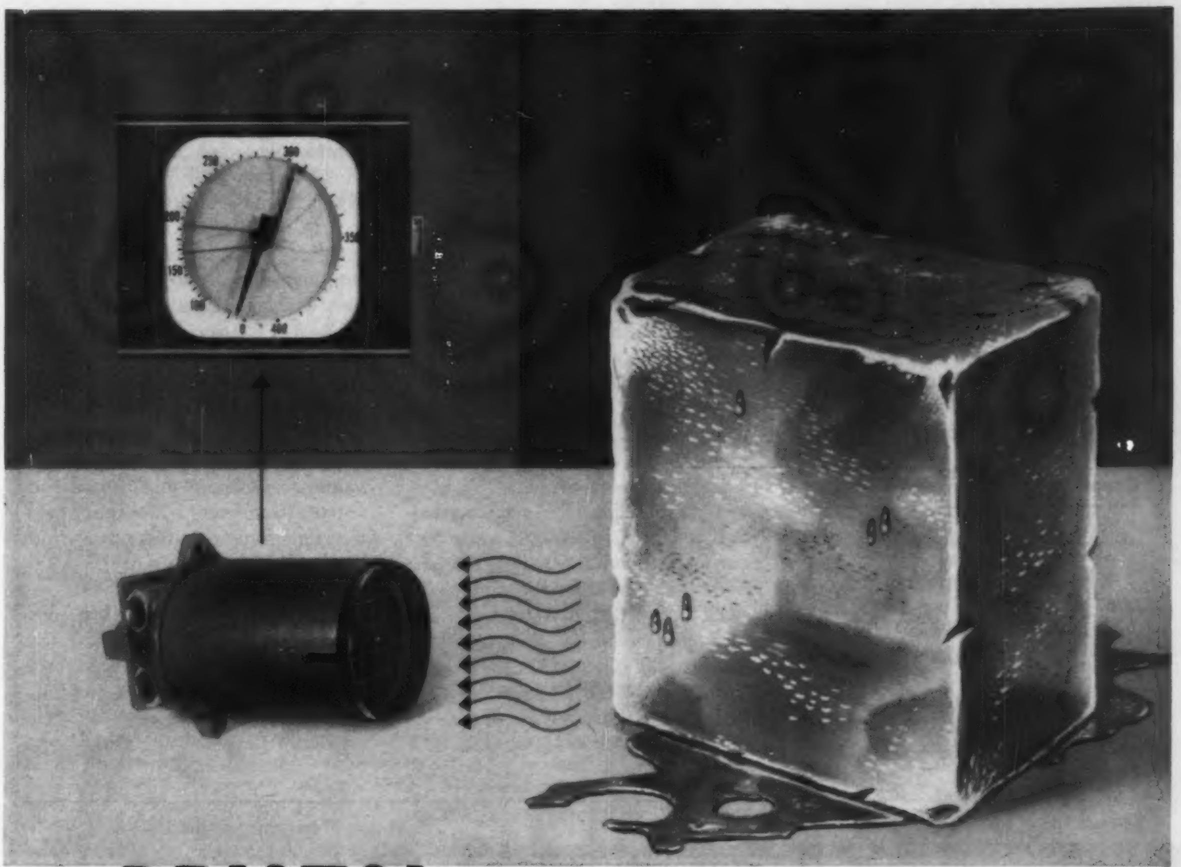
It is possible, however, to forecast in the middle 1960's and certainly by the late 1960's, based on the statistics in the report, the use of a major portion of existing titanium sponge capacity here in the United States in military applications. This estimate should be encouraging to a young, struggling industry.

LEE S. BUSCH

Aging of Normalized Steels

Digest of "The Role of Phosphorus in the Aging of Normalized Steels", by T. V. Cherian and N. J. Wadia, *Transactions* of Indian Institute of Metals, Vol. 10, 1956-1957, p. 83-93.

PHOSPHORUS IN STEEL is generally considered to be undesirable because of its embrittling and segregating tendencies. Therefore it is tolerated only in very small percentages. However, it also has beneficial properties since it tends to increase tensile and yield strengths



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Here's the first radiation pyrometer that really gets down to 0° F.

It's the Bristol Velotron Pyrometer System—so sensitive you can sight the radiation unit (at lower left above) on your hand and get an accurate temperature indication.

And on the high end, spans and ranges are available up to 1100° F or corresponding ranges in degrees Centigrade.

Charts and scales are direct reading, in degrees F or C, even on the lowest ranges. No laborious calibration runs, calculations; no curve consulting needed! And you get famous Bristol Dynamaster* Recorder accuracy —proven in thousands of installations.

Ambient temperature compensation is automatic, completely contained in recorder unit (no third unit needed), and allows use in ambients up to 135° F.

A simple knob adjustment allows compensation for emissivity characteristics of target material from black body on down.

Interconnection cables are standard copper wire; no special, preselected lengths required.

Write for complete technical data on this outstanding new Bristol contribution to industrial pyrometry. The Bristol Company, 155 Bristol Road, Waterbury, Conn. 9.31

*T. M. Reg. U. S. Pat. Off.

BRISTOL ...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Circle 988 on Page 48-A

Aging . . .

and heat resistance, creep resistance and corrosion resistance. For this reason, an investigation of the effect of phosphorus on carbon steels was undertaken. This investigation had the following objectives:

1. To evaluate phosphorus as an alloying element in low-carbon steels.

2. To determine the limits of solid solubility with varying amounts of the other alloying elements normally found in carbon steels.

Steel	Composition				
	P	C	Mn	S	Si
A	0.08	0.53	0.13	0.033	0.165
B	0.32	0.52	0.17	0.033	0.20
C	0.53	0.05	0.38	0.008	0.49
D	0.36	0.05	0.24	0.006	0.30
E	0.285	0.05	0.20	0.010	0.43
F	0.017	0.18	0.20	0.004	0.92
G	0.76	0.08	0.40	0.010	0.34
H	0.012	0.06	0.10	0.030	0.09

3. To determine the effect of phosphorus on the age hardening of plain carbon steels.

The experimental steels used in this investigation are in the table.

In addition to the elements listed in the table, steels D and E contained 0.72% and 0.91% Ti, respectively, and steel F contained 0.17% Ti and 0.21% Al.

All steels were made in a ½-ton induction furnace by melting low-carbon iron and then adding the requisite alloys. The melt was poured into 4-in. square ingots which were forged into 1¾-in. square billets and were finally rolled into ¾-in. diameter bars.

After rolling, all bars were normalized at 900° C. (1650° F.), and test bars of round-notched Izod bars were prepared from the normalized stock. The test bars were marked for identification and then renormalized at 900° C. (1650° F.).

Test samples of all the steels were subjected to tempering treatments at temperatures of 100, 200, 300, 400 and 500° C. (212, 390, 570, 750 and 930° F.), and samples of compositions C through H were also tempered at 600° C. (1110° F.). Samples were held at each temperature for periods of 5 min., 15 min., ½, 1, 2, 4, 7 and 15 hr.

After tempering treatments, the samples were water quenched to stop any uncontrolled aging. Room temperature aging studies were also conducted. After aging, the energy absorption and hardness were determined since these two properties were considered significant in assessing the amount of embrittlement resulting from aging. The hardness values were found to be more consistent than energy absorption values; therefore, more reliance was put on the hardness values in the evaluation of results.

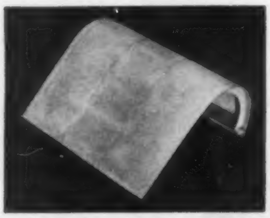
The results of the tests are summarized as follows:

1. The effect of phosphorus on the age hardening of steel is insignificant and may be considered nonexistent. Low-carbon steels with

Report on Developments of

New Fansteel 82 Metal in Hypersonic Vehicle Prototypes

Design and development work on hypersonic flight vehicles by Boeing Airplane Company and other missile and airframe manufacturers has indicated some important use-possibilities for Fansteel 82 Metal. This new columbium-tantalum-zirconium alloy was among the materials fabricated into prototype leading edges for materials capability evaluations at 2000°F and over. Results verified Fansteel's own tests proving the metal's high strength-to-weight properties at elevated temperatures.



Excellent Oxidation Resistance

Exhaustive tests in the Fansteel laboratories prove Fansteel 82 Metal far superior in oxidation resistance to pure columbium. Calculated on the basis of weight gain during exposure at 2000°F in air, 82 Metal is ten times as resistant as the pure refractory metal. Sixteen-hour, 2000°F test in flowing air showed remarkable low scaling of 0.01 cm.

Tensile Properties of Sheet

The encouraging results of Boeing's prototype tests indicate 82 Metal's suitability for airframe and missile material. Average tensile properties are shown below.

Fansteel 82 Metal Easily Formed

In addition to its high temperature properties, 82 Metal has excellent fabricating characteristics. Ductile welds are made with little or no tendency to fracture in heat affected zones. It is easily fabricated at room temperatures, as worked or annealed. Its melting point is 4550°F and density 10.26 grams per cc (0.371 lb. per cu. in.).

Welding the Boeing prototype in an inert atmosphere chamber using tungsten inert gas process.

Design and Engineering Help

Fansteel engineers and metallurgists are now working with many other firms in adapting Fansteel 82 Metal to specific areas. They will be glad to cooperate with your own designers and production people in studying and applying this useful new metal. Just send us your print or part sample, or call in the Fansteel representative.

Available From Stock

For experimental purposes . . . Fansteel 82 Metal is available from stock in ingots, forgings, bar, rod, plate and sheet. Let us keep you informed of developments concerning this new alloy as they occur. Write for the latest technical bulletin.

TENSILE PROPERTIES OF SHEET

TEMPERATURE Degrees F	ATMOSPHERE	ULTIMATE TENSILE STRENGTH, psi.	YIELD STRENGTH .2% offset, psi.	ELONGATION % in 1 in.
70-80	Air	76,000	65,000	12
1800	Argon	59,000	53,000	1.5
2400	Argon	19,000	15,000	14

Photos Courtesy of Boeing Airplane Company

FANSTEEL

FANSTEEL METALLURGICAL CORPORATION
NORTH CHICAGO, ILLINOIS, U.S.A.

K602

Circle 999 on Page 48-A

Aging . . .

a phosphorus content below 0.29% do not age harden. Aging between 200 to 300° C. (390 to 570° F.) is followed by softening.

2. The embrittling effect is a function of the phosphorus content and in low-carbon steels becomes very noticeable above 0.29%P.

3. Below 600° C. (1110° F.) the minimum solubility of phosphorus in low-carbon steels is about 0.29%.

4. Titanium additions to low-carbon steels lower the hardness and improve the toughness.

5. High-carbon steels are adversely affected by the addition of phosphorus.

6. Phosphorus contents below 0.29% have beneficial effects on low-carbon steels.

7. Hardness measurement is a more sensitive method than Izod energy absorption for studying the age hardening susceptibility of phosphorus steels.

BERNARD TROCK

KNOW YOUR ALLOY STEELS . . .
This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Quenching Media for Alloy Steels

In the quenching of alloy steels, several points require consideration, among them being the size and shape of the piece, the type of steel involved, the quenching medium, and proper agitation of the quenching bath.

The composition of the steel has an important bearing on the selection of a quenching medium. As an example: shallow-hardening steels require a fast cooling rate, whereas deeper-hardening steels require progressively slower rates as the alloy content increases.

Three commonly used types of quenching media for alloy steels are water, oil, and air. These are discussed below in the order of quenching severity:

(1) WATER. Since shallow-hardening steels require fast quenching rates, water is the quenching medium used to harden them. Agitation is generally used to help in obtaining the desired cooling rate. The use of brine solutions have proven beneficial when sufficient agitation cannot be obtained. It should be noted that the quenching rate drops as water temperature is increased. The range of 70 deg to 100 deg F is recommended.

(2) OIL. An oil quench cools more slowly than water, and faster than air. Oil-hardening steels can be hardened with less distortion and greater safety than water-hardening steels. Mineral oils are generally used because of their low cost and relatively stable nature.

(3) AIR. If sufficient alloying elements are present, critical cooling rates are decreased to the extent that certain steels can be quenched in either still or forced air.

While the choice of quenching medium is of prime importance, there is another factor that should not be overlooked. This is the agitation of the quenching bath. The more rapidly the bath is agitated, the more rapidly heat is removed from the steel, and the more effective the quench.

Bethlehem metallurgists will gladly help you with any problem related to quenching or other phases of heat-treatment. They are men of long practical experience in this field, and they understand fully the advantages and limitations of each method. Always feel free to call for their services; their time is yours, without obligation.

Remember Bethlehem, too, when you are next in the market for AISI standard alloy steels, special-analysis steels, or carbon grades. We are always in a position to meet your needs promptly.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

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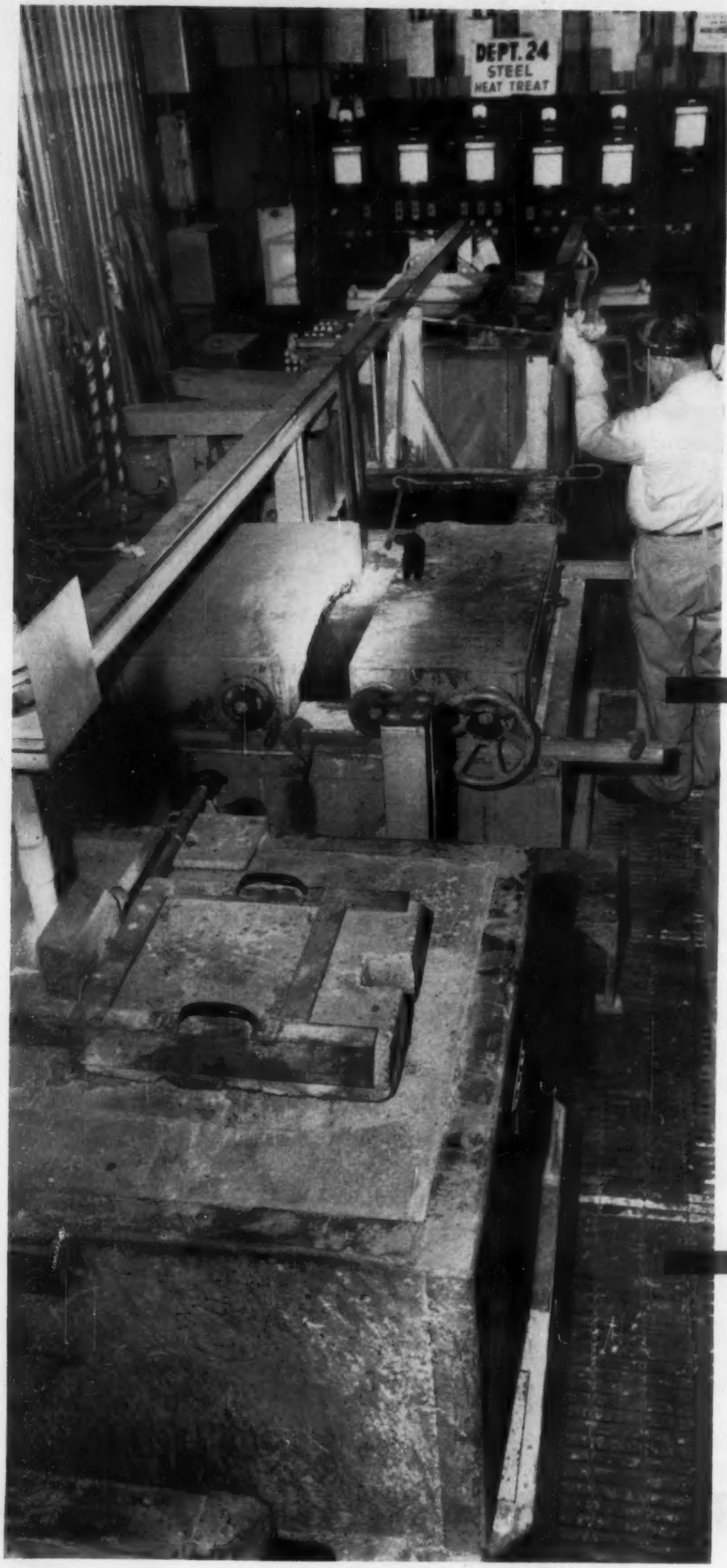

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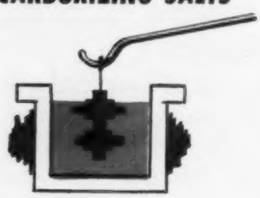
CARBURIZING SALTS



Available in a variety of formulations to meet any case hardening requirement. These are the well-known Perliton Liquid Carburizers for fast, uniform heat treatment, minimum distortion, longer part life and a true carbon case. Most important . . . the savings possible on equipment.

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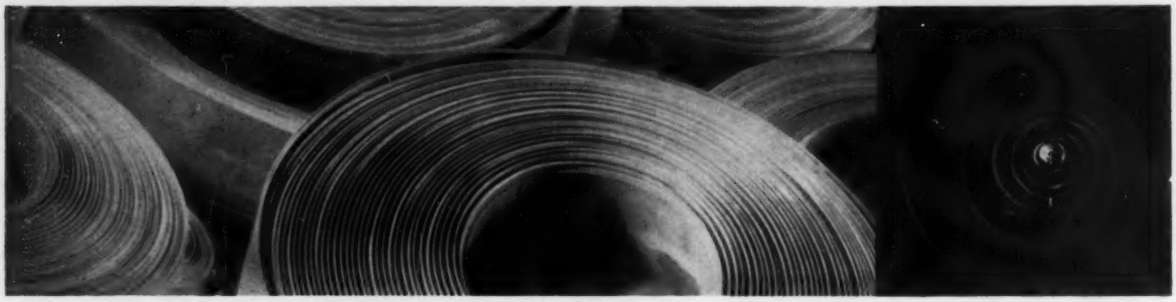

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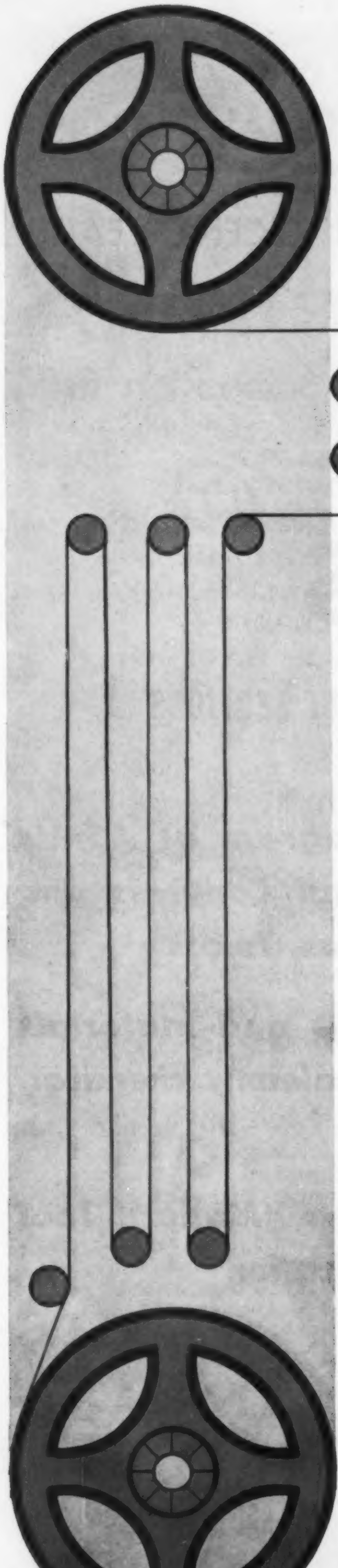

EVERY TWO WEEKS THIS TAPE CAN DELIVER THE WORLD OF CURRENT TECHNICAL LITERATURE TO YOUR DESK

Now you can say good-bye to page-by-page searching of hundreds of magazines for the technical information you need . . . because the American Society for Metals is coding, on electronic tape, every current metals article from over 600 of the world's leading magazines . . . plus patents, government reports, books, everything published. This will be a continuing process. The tape will contain, in code, every article you will read and the many articles you won't read because you will never see them.

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ASM's Information Searching is a most important advance in modern research tools. It is a major breakthrough for any firm which looks to technology for the solution to metals problems. For firms of any size, it can inexpensively provide what until now was impossible; a complete and continuing world library of specific information without the turning of a page. A descriptive booklet will answer any questions you may have—how Information Searching can save you and your firm the time and money now spent for page-by-page literature searching—how it can keep you completely current. For your copy, mail this coupon to: American Society for Metals • Documentation Service • Metals Park • Novelty, Ohio.

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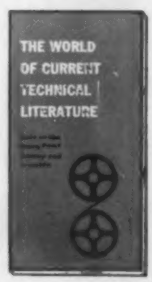

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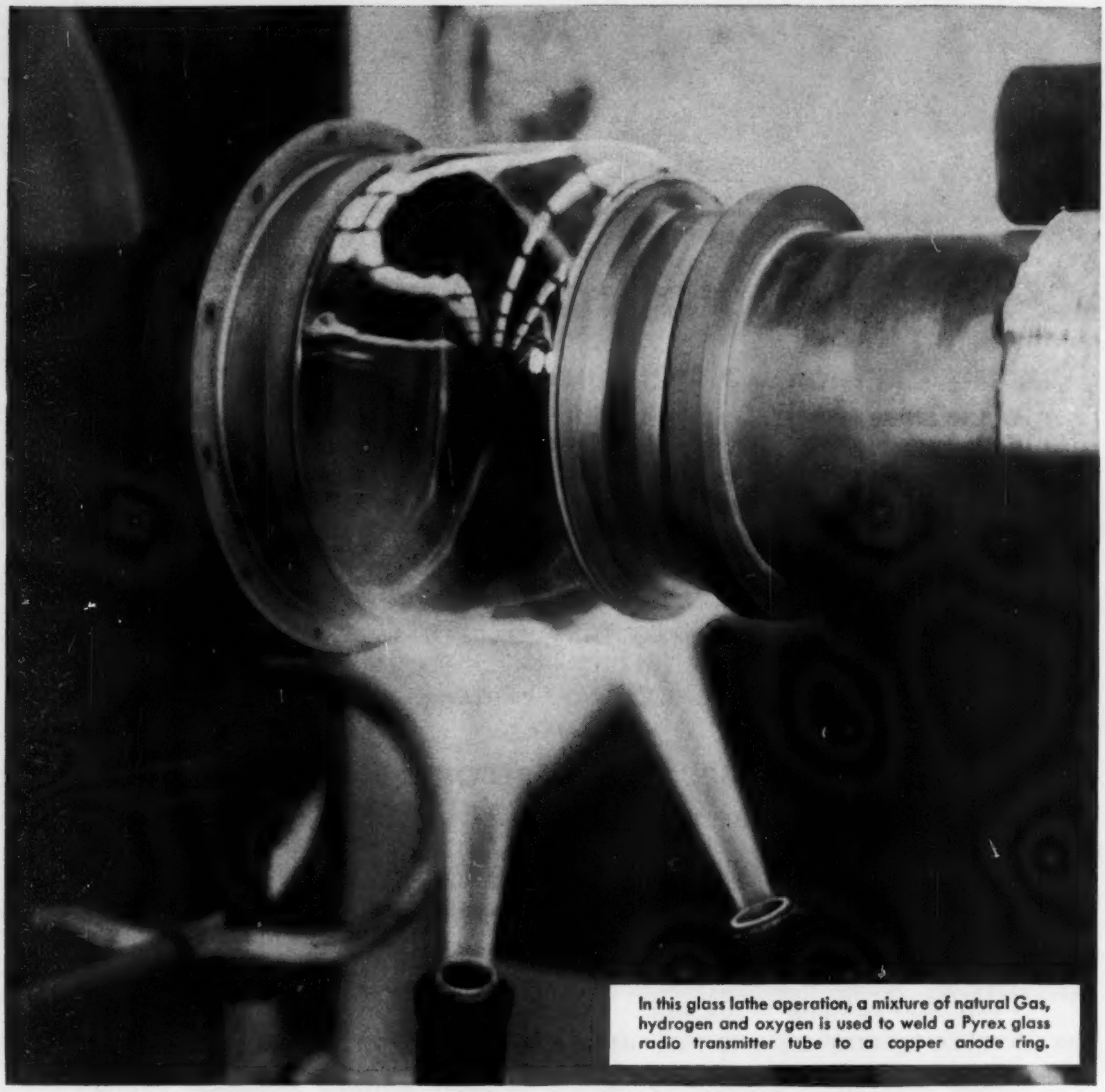

In this glass lathe operation, a mixture of natural Gas, hydrogen and oxygen is used to weld a Pyrex glass radio transmitter tube to a copper anode ring.

RCA welds glass to metal at over 2000° F. ...thanks to GAS

Natural Gas is used to weld glass to metal in the production of radio and television tubes of many types at the RCA Electron Tube Division plant in Lancaster, Pennsylvania.

To effect the weld at over 2000° F., a mixture of natural Gas, hydrogen and oxygen maintains the high welding temperature on the Pyrex glass and metal parts as they rotate on a glass lathe. A Gas flame is then used to control and equalize the cooling of the glass down to the 900-600° F. range.

For information on how Gas can help you in your production operations, call your Gas Company's industrial specialist. He'll be glad to discuss the economies and superior results you get with Gas and modern Gas-fired industrial equipment. *American Gas Association.*

•

See Playhouse 90 with Julia Meade on CBS-TV. Watch local listings for time and station. Sponsored by your Gas Company and the Gas Industry.

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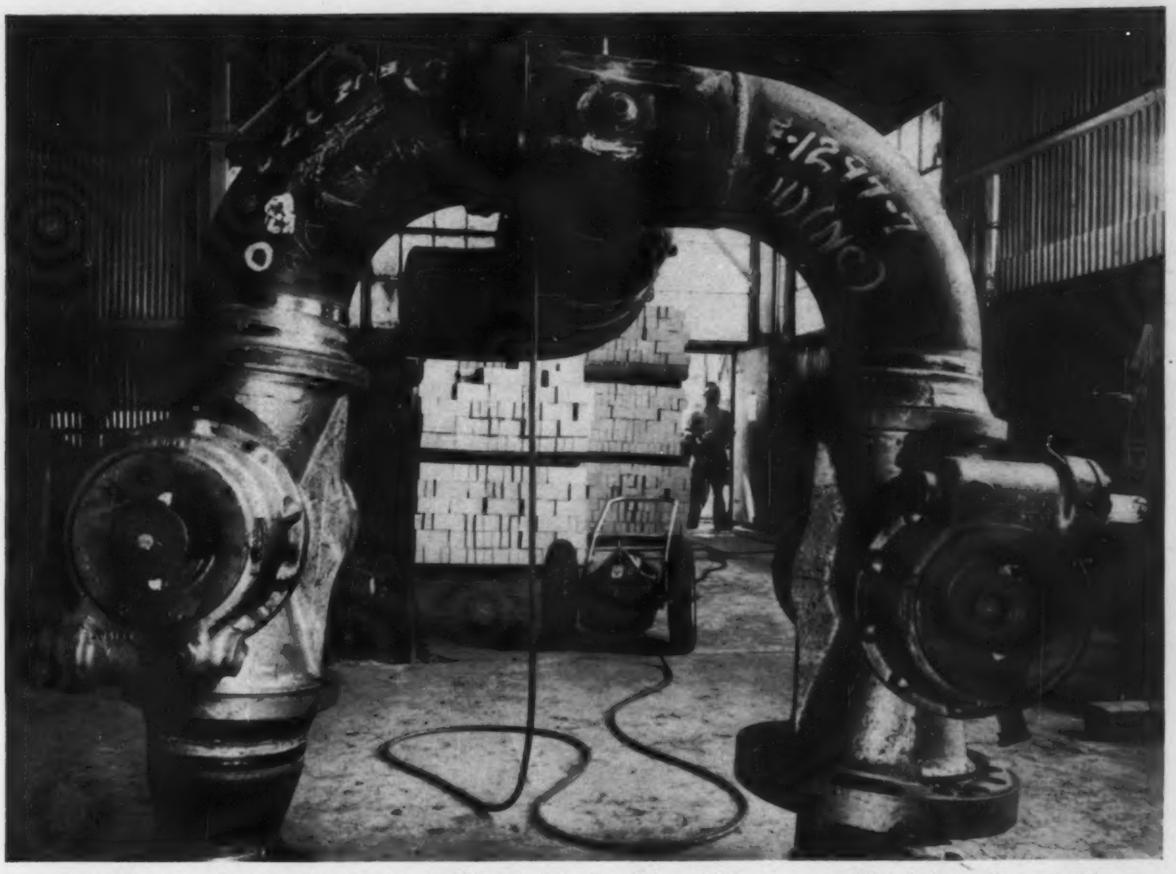
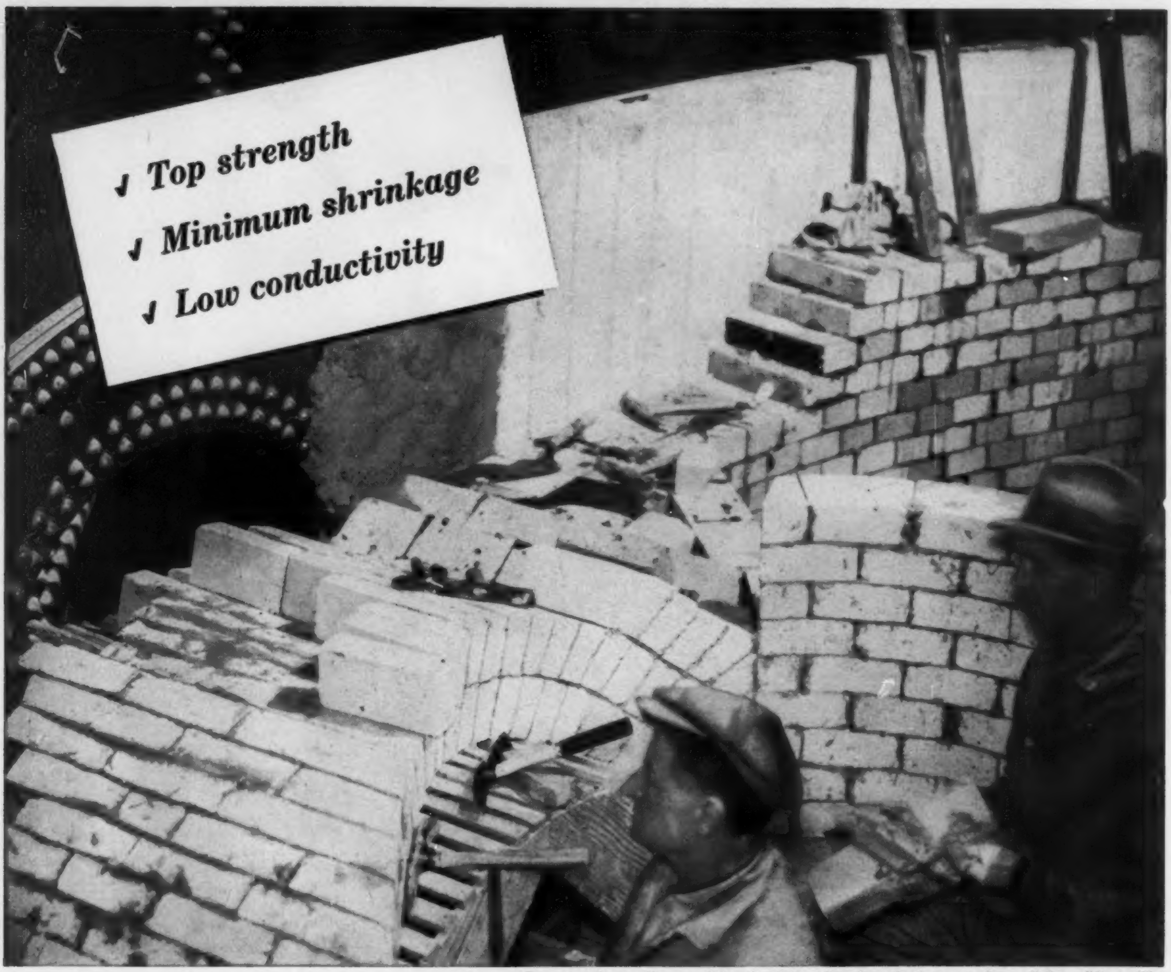


The entire circumference of the left hand weldment at the Tee fitting of this pipe assembly is being radiographed in a single exposure with a Model 50 Multitron. The unit can handle any isotope suitable for gamma radiography . . . and up to four separate sources can be contained in the same machine. A wide variety of exposures can be made—internal, panoramic and beam. Model 50 travels with ease anywhere in plant or field, requires no external power.

Circle 1001 on Page 48-A



Superex is easily combined with other insulations such as Johns-Manville Thermobestos®, J-M 85% Magnesia or J-M Insulating Fire Brick.

Only Johns-Manville Superex insulation performs 3 ways better at high temperature!

Few industrial products are so outstandingly superior, or so widely used in their area of application, as Johns-Manville Superex® Insulation.

A block insulation formulated of diatomaceous silica and asbestos for furnace and other applications, Johns-Manville Superex brings many advantages to high-temperature service—each contributing to reduced construction, maintenance and operating costs.

Superex is installed with measurable savings in time and labor! It is easy to cut and handle . . . weighs only 2 lbs. per sq. ft. per inch thickness . . . available in a wide variety of large block shapes and sizes. At high temperature—the material's excellent insulating value, thermal stability and resistance to shrinkage keep fuel costs low. Equally important—Superex saves on maintenance, too . . . easily withstands the daily abuse of normal service.

Send for your copy of IN-190A, the 12-page design and technical data brochure. It lists suggested applications—gives complete heat transmission tables and performance data. *Write for it today.* Address Johns-Manville, Box 14, N.Y. 16, N.Y. In Canada, Port Credit, Ont.

Saves waste. Superex comes in 7 standard thicknesses from 1" to 4". Other sizes available on order.

JOHNS-MANVILLE

JOHNS-MANVILLE JM PRODUCTS

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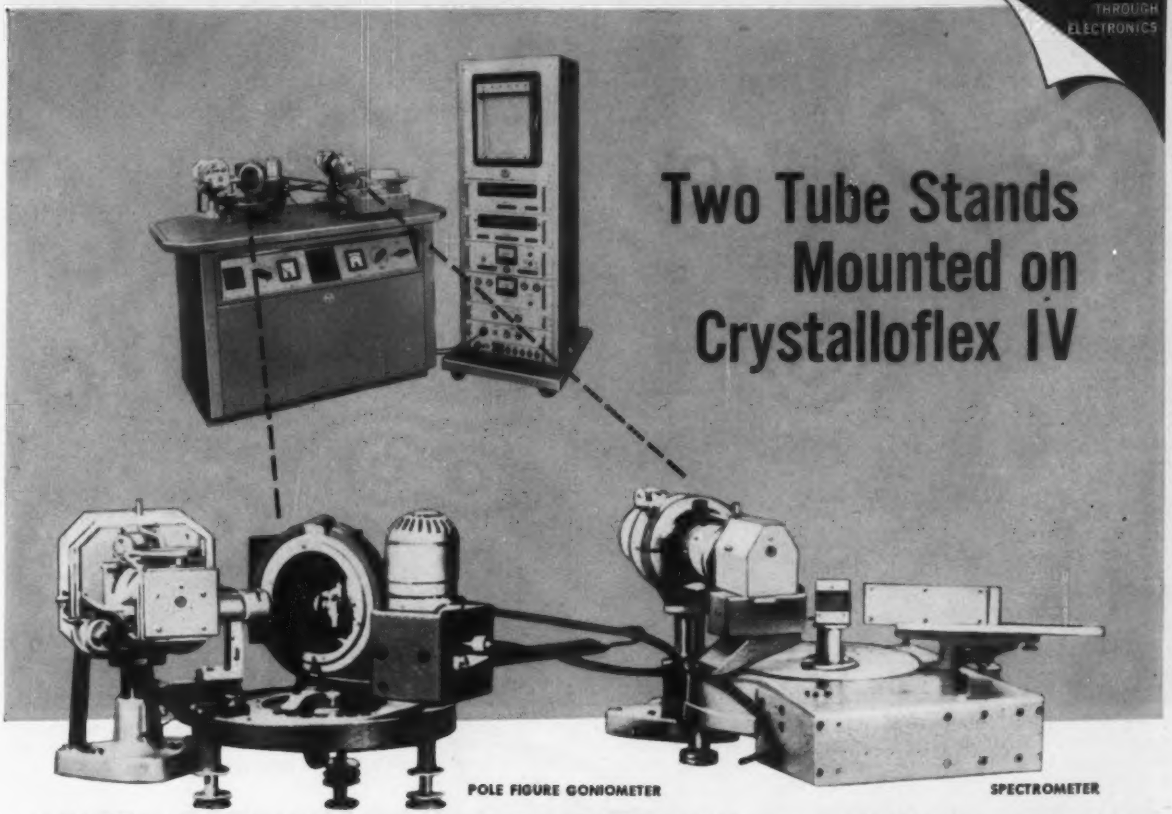
X-RAY DIFFRACTION AND SPECTROSCOPY EQUIPMENT

ANOTHER WAY RCA SERVES INDUSTRY THROUGH ELECTRONICS



Fast change-over without realignment!

With two tube stands mounted at once on the RCA Generator, you're ready for either x-ray diffraction or spectroscopy. Change-over is made by merely moving the cable connection from one stand to the other. It saves time in set-up and alignment . . . in switching from spectroscopy to diffraction or vice-versa.

Conveniences such as this, as well as unusual flexibility and fine craftsmanship, are making this RCA equipment one of today's most frequently specified lines. Installations have already been made in a number of the nation's foremost research laboratories where these instruments are demonstrating their efficiency and versatility.

A Vacuum Spectrometer for analysis of elements with atomic numbers below 22 is but one of a wide range of attachments and accessories available. For spectrochemical analysis, the regulated and filtered DC power supply will prove invaluable. Also contributing to the unequalled adaptability of this equipment is the compact electronic circuit panel complete with built-in pulse height analyzer and convenient plug-in components.

As a basic facility for x-ray diffraction film studies, RCA offers a Table Model Generator, complete with an assortment of cameras *at a cost of less than $4000.00.*

RCA also offers the EMU-3 Electron Microscope—the most widely used instrument of its kind—providing direct electron image magnification to 200,000X.

Service and installation supervision on all RCA Scientific Instruments are available everywhere through the offices of the RCA Service Company, Inc.

For further information, write to Radio Corporation of America, Dept. E-72, Building 15-1, Camden, N.J. In Canada: RCA VICTOR Company Limited, Montreal.

RCA Tmk(s)®

RADIO CORPORATION of AMERICA

SCIENTIFIC INSTRUMENTS ■ CAMDEN, NEW JERSEY

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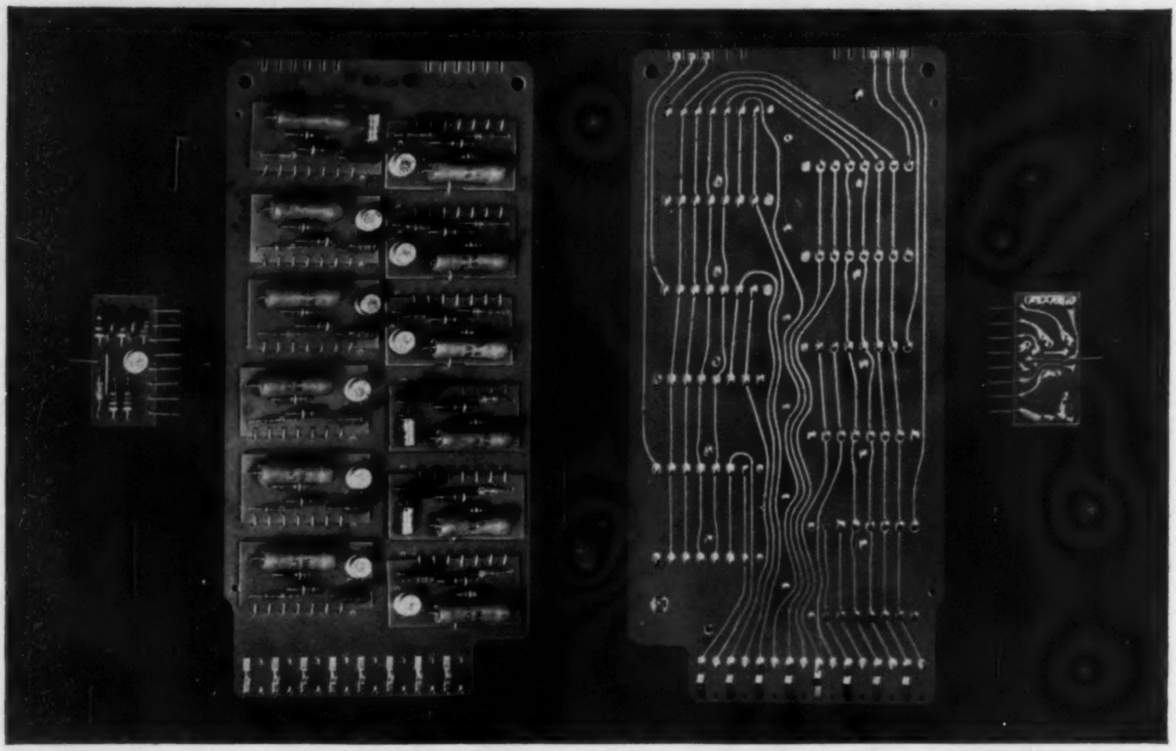
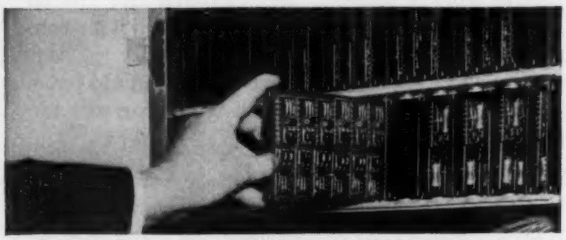
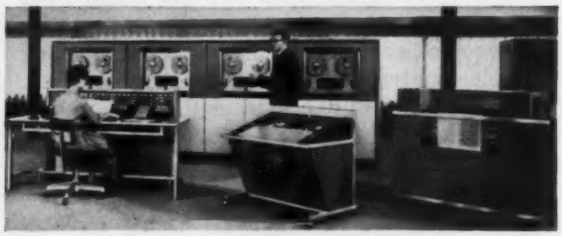


In the electronic logic elements of the RCA "501" data processing system, transistors and other small components are mounted on plastic wafers with printed-circuit wiring (small units right and left, above). The wafers, in turn, are mounted on thin plastic boards, also with printed circuits (center, above). This modular construction reduces size of the system by 75%, increases reliability, reduces maintenance.

PRINTED CIRCUITS OF COPPER AND ALL-TRANSISTOR DESIGN HELP MAKE 75% SIZE REDUCTION IN RCA DATA PROCESSOR



Modularized circuit elements are installed in the system by sliding them in place. Contacts on outside edge make possible quick checkout and testing without removing boards. Many thousands are used in each system.



The "501" is designed to handle paper work—bills, reports, payrolls, etc.—accurately, economically, and at extremely high speed. It serves businesses ranging from banks and utilities to steel mills.

With the growing importance of miniaturization and reliability in electronics and nucleonics, Anaconda electrical copper products take new and varied forms—find new and more sophisticated uses.

In the compact new all-transistor data processing system shown above, the printed circuits are etched from Anaconda "Electro-Sheet" copper foil. This is electrodeposited paper-thin copper with quality carefully controlled to meet NEMA specifications. Bright on one side, it has a matte finish on the other for a firm bond to the circuit board. "Electro-Sheet" is furnished in various thicknesses to exceptionally close tolerances.

In other fields, the growing need for compact electrical assemblies which can handle high current densities calls for hollow copper conductors for fluid cooling. And for new environmental conditions, more difficult application needs, there are new copper alloys.

METALLURGICAL ASSISTANCE. Whatever your problem in electrical conductors, Anaconda metallurgical specialists will gladly help you select the metal—and the form or shape—best suited to your needs. See your American Brass representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

5946

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ELECTRICAL COPPER PRODUCTS

Made by The American Brass Company

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BEHIND THE BYLINES

In this issue appears the first article of a comprehensive four-part series on Flight in the Thermosphere; this month's article tells the materials requirements for thermal protection systems, while materials for heat sinks will be covered in April, ablation sublimation and transpiration systems in May and radiative systems in June. The authors, William J. Harris, Jr., and William S. Pellini, shown below discussing small-scale tests on nose cone models, have both been engaged in the study of materials critical to defense applications since the early 1940's. During the early war years, Bill Pellini worked on gun barrel steel research at Carnegie Tech and steel cartridge case development at Frankford Arsenal. Later he served as a naval officer at the Naval Proving Ground working on armor and projectile development. Following an interlude of nuclear metallurgy work at the Oak Ridge National Laboratory, he joined

the Naval Research Laboratory in 1949 to head casting and welding research and then assumed his present position as superintendent of the metallurgy division.

Bill Harris's work on aircraft armor in World War II was followed by broader studies of ferrous alloys at the Naval Research Laboratory. He joined the Materials Advisory Board in 1951 and from 1954 to 1957 was assistant to the director at Battelle Memorial Institute and an active participant in the organization and operation of the Titanium Metallurgical Laboratory. Since 1957 he has served as executive director of the Materials Advisory Board and planned and executed definitive studies on beryllium, steel, titanium, refractory metals, solid rocket motor materials, and thermal protection systems. He has also participated in the technical material work of the Advisory Group on Aeronautical Research and Development to NATO.

Bill Pellini spends his off-hours with his family (he has three children) in the mountains, beaches, waterways and swamps of the Washington area – hiking, shooting or camping. The majority

of Bill Harris's extra time is devoted to his family (he has two children) and his community, Mayoane Reserve. As president of community development, organizations, he has been active in retaining a large area of woodlands and waterfront in its natural state. He is also a voracious reader and an active fisherman.

The article on "Electroforming a Liner for Mach-6 Wind Tunnel" (p. 76) is based on George E. Sutila's work in Douglas Aircraft's Aerophysics Laboratory. With Douglas for ten years, he was in charge of the structure testing of Navy carrier-based aircraft until he was assigned to the Laboratory four years ago. Since then, he has assisted in the mechanical and structural design of the Trisonic One-Foot Tunnel, the Supersonic Four-Foot Tunnel and the Hypersonic 27-Inch Tunnel. As supervisor of operations and equipment at the Laboratory, he is currently in charge of the design of two additional facilities, the Hypervelocity Impulse Tunnel with Mach numbers up to 20, and a Ballistic Range with model velocities reaching 15,000 ft. per sec.

Mr. Sutila's other interests include travel (particularly in desert areas) photography and the study of American Spanish.

Winston H. Sharp, co-author with J. E. Coyne (see Behind the Bylines, December 1959) of "Beta Titanium for Solid Rocket Motor Cases", joined Pratt & Whitney Aircraft in 1942 and until 1949 served in various positions in the Materials Control and Materials Development Laboratories. Since 1949 he has been engineering metallurgist. While his principal concern has been with materials for aircraft gas turbines – with materials ranging from aluminum to high-temperature alloys – Pratt and Whitney's expanding activity in the field of rockets and missiles has recently led to his involvement with high-strength steels and titanium alloys for solid rocket motor casings.

A fervent fisherman, he fishes for trout near his home in Connecticut (when he can't get away to angle for Atlantic salmon in the rivers of the Gaspé and New Brunswick). He also enjoys reading "sufficiently to be conversant with a wife and two daughters, 15 and 20", and going to his cabin which boasts an aluminum-hooded free standing fireplace (which, he is quick to add, really *works*).

Behind the Bylines . . .

Glenn E. Selby, pictured at right holding one of the extensometers used to test thin sheet steels (see his article on p. 85), has spent nearly 18 years in the metallurgical testing field at Armco Steel Corp.'s Research Laboratories. Now senior metallurgist in charge of the mechanical testing section of the Laboratories, he is responsible for the determination of mechanical properties on the wide variety of Armco products.

The question "Which Bell Furnace?" (p. 87) is competently answered by Lloyd Johnson, based on eight years in General Electric Co.'s industrial heating department. With G.E. 20 years, his present assignment includes the dual responsibility of getting into commercial use the new ideas which come out of the laboratory and seeing that his department's offering meets the new and changing needs of the industry.

In addition to his work with vacuum furnaces, he has recently been working with furnaces for bright annealing stainless steel in very pure hydrogen atmospheres; he is shown above examining a sample of this stainless.

Mr. Johnson's family of five includes a wife, two lovely daughters and an energetic wire-haired terrier. Golfing, fishing, ice skating and gardening are his preferred pastimes.

J. F. Libsch has written several articles on the metallurgical aspects of induction heating, including the one on p. 94. Professor of metallurgy at Lehigh University, he has also been a consulting

metallurgist for Lepel High Frequency Laboratories for the past 14 years. His primary interest lies in the field of industrial metallurgy, particularly the area of heat treatment and materials.

Well known to ASMembers, he has been on many Society committees – usually as chairman. His chairmanships have included the Handbook Sub-Committee on Induction Hardening and Tempering, Transactions Committee, Advisory Committee on Metallurgical Education; he is currently a member of the Publications Policy Committee, and he is also a past chairman of the Lehigh Valley Chapter.

For relaxation, Joe turns to camping (with his wife and three boys during the summer) in the United States and Canada, to golf in the summer and, when he has to put up his clubs, to field archery in the winter.

The continental appraisal of light alloy castings on p. 115 was made by a well-qualified consulting metallurgist in the Netherlands – L. J. G. van Ewijk. Dr. van Ewijk was an inspector of aircraft and head of the materials section of the Netherlands' National Aeronautical Laboratories for more than 25 years. After the war he joined N. V. Industrie Vassen in the Netherlands as chief metallurgist and head of laboratories. During that time, as an inspector for aircraft castings, his interest focused on the development of light casting alloys and their production problems. Since 1959, he has been a free-lance metallurgist.

Welding has been Alexander Lesnewich's primary interest since he began his metallurgical studies at Rensselaer Polytechnic Institute. His professional career has been spent with the Air Reduction Co.'s Central Research Laboratories, working broadly in the welding field, and he is now supervisor of welding research in the Laboratories.

Along with most fathers, his hobbies are temporarily being impeded by Cub Scouts, Indian guides and other pressures from three young and energetic sons. But some of these interests, such as gardening, cabinet-making and high fidelity, are being exploited in making a home out of a new house.

ADVERTISERS INDEX

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